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PROCEEDINGS OF THE RESEARCH SYMPOSIUM ON PHYSICAL SCIENCES AND ENGINEERING

MISSISSIPPI STATE COLLEGE
1953

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OF

THE RESEARCH SYMPOSIUM

ON

PHYSICAL SCIENCES AND ENGINEERING

COMMEMORATING THE SEVENTY-FIFTH ANNIVERSARY

OF

MISSISSIPPI STATE COLLEGE

HELD ON APRIL 24 AND 25, 1953

RESEARCH SYMPOSIUM

COMMEMORATING

THE SEVENTY-FIFTH ANNIVERSARY OF

MISSISSIPPI STATE COLLEGE

A symposium of the physical sciences and engineering was held at Mississippi State College on April 24 and 25, 1953, during which time representatives of industry and scientific education met to discuss the complementary nature of academic and industrial research, to report on progress in their individual fields and to pose challenging unanswered questions to the students and researchers comprising their audience.

To open the program the noted concert pianist and professor of music at Wisconsin, Gunnar Johansen, played an improvisation of a theme on Leonardo da Vinci to symbolize the spirit of adventure and vision necessary for scientific advancement. Improvisation, Mr. Johansen explained, was advocated by the great Renaissance scholar and artist at a time when blind acceptance of what had been written by the sages of antiquity stifled originality in musical composition as well as scientific progress. Mr. Johansen also played an ancient Augustinian chant and a selection from Johann Sebastian Bach in order to illustrate, on the other hand, the eternal verity of mathematic precision, in the first case in the production of a simple theme, in the latter in the production of a complex structure of themes.

The distinguished speakers of the symposium followed Mr. Johansen's musical introduction. They included Dr. A. E. Ruark of the Physics Department at the University of Alabama; Dean G. A. Garratt of the School of Forestry at Yale; Dr. Frank J. Soday, who is Director of Research at the Chemstrand Corporation of Decatur, Alabama; Dr. F. O. Ringleb, who is a staff mathematician of the U. S. Naval Aircraft Factory and a Consultant to Princeton University; Mr. H. N. Muller, Assistant to the Vice-President in charge of Engineering at Westinghouse; Dr. Paul E. Klopsteg, Associate Director of the National Science Foundation in Washington, D. C.; Mr. Mace H. Bell, Assistant Director of Engineering at the American

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Institute of Steel Construction, Inc., New York, New York; Mr. Kenneth R. Daniel, who is General Chief Engineer of the American Cast Iron Pipe Company of Birmingham; and Mr. Grover Loening, Aviation Consultant at MillNeck, New York, who is one of the fathers of powered flight.

The opening session on Friday morning was presided over by Dr. Harold vN. Flinsch, and guests and speakers were welcomed by Mr. Ben Hilbun, Acting President of Mississippi State College. Speakers of the afternoon were introduced by Dr. M. P. Etheredge, Dean of the School of Science, who also presented Dr. Klopsteg, the dinner speaker for the evening. Saturday's program was presided over by Dr. Herbert Drennon, Dean of the College and the Graduate School.

The committee responsible for the symposium was composed of the following members: Dr. August Raspet, Chairman, from the Department of Aerophysics; Professor Robert T. Clapp of the Forestry Department; Dr. Paul H. Dunn of the Geology Department; Professor Mathew L. Freeman of Engineering; Dr. M. P. Etheredge, a member of the Chemistry Department and Dean of the School of Science; Dr. Arnold J. Gully of Chemical Engineering; and Dr. Irl E. Howell of the Physics Department.

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PHYSICS AND NATIONAL PROSPERITY

By Dr. A. E. Ruark

Mr. Chairman, Ladies and Gentlemen:

Let me offer congratulations to the faculty and the officers of Mississippi State College on this anniversary. No man can fully appreciate the tremendous power of a college or university because its influence goes out in many directions, through many people, but we know that the progress of a whole area may depend greatly on the vigor and the progressive spirit of the institutions of higher learning in that area.

Therefore it is natural that the chief topic of this celebration is research. We know that a college must manufacture knowledge, not merely disseminate knowledge, in order to do its full duty to the people who support it. We know that most of the great advances in science and technology have been born in the seats of higher learning. For this reason, my talk today will deal with the far-reaching consequences of fundamental research, and since I am a physicist, the illustrations will come mostly from the field of physics. Nevertheless, the points we shall cover are general ones, applying to all the fundamental sciences.

1. The Importance of Fundamental Science in Our Economy.

Within the lives of people in this room, the power of science has increased until today it is the all-important social force. The actions of statesmen, of business leaders and leaders in agriculture, are, in the long run, determined by the status of our technology and our scientific knowledge. For example, there could be no rational program of public health administration, no rational control of our water and milk supplies, without the knowledge supplied by chemists and bacteriologists, knowledge based on patient investigations in the laboratory, extending over several decades. There could be no rational planning of world girdling communication systems, without the scientific knowledge of electricity and its control, worked out in physical laboratories over the past one hundred and fifty years.

Beneath every great advance in technology there flows a deep quiet current of scientific advance, determining the nature of our technology and the actual conduct of our lives.

In speaking to you about Physics and National Prosperity, I shall have to define my terms. By prosperity I do not mean full pocket and full paunches. We know there would be plenty of goods for all if our social institutions were so developed that each one could get his reasonable share. By prosperity I mean the good life in its totality. The word includes both material and intellectual prosperity. It includes a satisfactory understanding of the nature of our physical world and of our proper relations with our fellow men. The time has long gone by when a man can call himself educated if he has merely some knowledge of literature, history, political science, jurisprudence and the world's religions. Today something more is necessary. Today a man is illiterate if he does not have some knowledge of mathematics, of each of the great fundamental sciences, and of the main currents in industry and technology. A man without these accomplishments is no better than a Greek. He is living in the ancient world, and not the twentieth century. In the near future, nay even now, the real prosperity of a nation will be judged not by production figures on meat and housing and clothing, but by the general status of its education, its laboratories, and its cultural and intellectual activities. Of course, a certain measure of physical comfort is essential to the proper development of the more enduring intellectual satisfactions, but we must recognize that the battle against poverty, the battle for release from heavy physical toil, is fast being won. And it is being won because of mass production, because of electric power, because of a host of progressive industries, based on sound technology, which in turn is based on sound science.

And now a word about the part played by physics. I shall define physics as the body of fundamental, general facts about matter and radiation, which underlies all the other material sciences. According to this definition, physics includes large parts of mathematics. Physics is the central core of every material science, the binding force which holds the whole elaborate business together. In saying this, I mean to emphasize the essential kinship of all sciences, and of all scientists. I do not know where physics leaves off and chemistry begins. The same holds true for geology, biology, medical science and engineering.

It is natural and understandable that in the industrial exploitation of natural resources and natural forces, chemistry and geology and applied biology achieved many of their triumphs before physics could pile up a creditable record of achievement. But in the more recent stages of the industrial revolution, the foundations for great new industries have been provided increasingly by physical discoveries. To show this, I shall give a few illustrations.

The development of the electrical industry comes from the discovery of electromagnetic induction by Henry and by Faraday. The telegraph and the telephone, the vacuum tube and the transistor, all come from the activities of physicists. The same is true of the entire art of radio communication, whose foundations were laid by Maxwell and Hertz. X-rays and radioactivity came from the hands of men who were studying physical phenomena for their own sake and not in the hope of financial reward.

To give another illustration, World War I is often described as a chemist's war, and World War II as a physicist's war. There is a great deal of truth to this. While the actual business of making the ships and the weapons was a mighty achievement of American industry, the physicists called the tune in World War II. They really decided what weapons would be produced.

People were greatly impressed by the atom bomb, which provided a sour ending to a very sour experience for the human race. Largely because of the A-bomb, and because of the controversies over work on the hydrogen bomb, people have come to expect that whatever happens, the physicists and the chemists will rub some kind of Aladdin's lamp and conjure up a flock of powerful genies, to protect Western civilization and to preserve the institutions of freedom throughout the world. For two good reasons, this is a false expectation. First of all, the physicists of America have no monopoly on natural forces. Physicists anywhere can make the atom bomb, as we learned in 1949. Secondly, the prospect for providing great new industries, or wholly new classes of weapons, through exploitation of known physical facts, is rather bleak. We have told you all we know; we have shown you all our tricks; we

have given you all the bread, and now the cupboard is bare. If you want a new weapon, you will have to go to the experts in biological warfare,--assuming that you can find anyone who is really an expert in this new and untried field. If you thought that this talk would be a commercial plug for having more physicists in industry, please get ready to change your minds. Why should the physicists advertise, when there are five jobs at higher salaries waiting for everyone of us? The real problem is to provide enough fully-trained physicists to meet the needs of the country. Only the colleges and universities can do this. Furthermore, there is a limit to the number of suitable candidates for advanced degrees in physics, a limit to the number of young men who can stand this training. Modern physics is a man-killing, competitive profession. Only roughnecks with strong backs and giant brains should enter physics.

Furthermore, physicists of the better classes do not want to work on minor details of the arms program. They want to work on fundamentals, because the fundamentals have been relatively neglected for the past few years. Our best contributions to the ultimate good of America will come from putting more emphasis on fundamental research.

There are still great domains of ignorance to conquer, in which the services of physicists are needed at every step. Let me illustrate.

The production of nuclear power is one of these domains.

The utilization of physical techniques and principles in chemistry, biology and medicine is another.

I shall not elaborate on the great problems which confront us in understanding the fundamental particles, namely, the electron, the proton, the neutron and all their cousins.

Looking aside from this great field, we may expect striking advance in the closely related subjects of biophysics and biochemistry. This is true largely because the development of plentiful supplies of radioactive isotopes at Oak Ridge gives the scientist a means for looking into the finer details of life processes. We may expect wholly new developments in chemistry, biology, agriculture and medical science as a result of research with these powerful tools. The radioactive tracer substances come to us as a <u>by-product</u> of the discovery of uranium fission. In the long run, the significance

of uranium fission will lie not in the production of weapons, but in the understanding of atoms, molecules, and living organisms.

2. Support for Fundamental Science.

Now let us turn to the matter of support for fundamental research. You may be surprised that I am worried about the status of this support when we know that the amount of such research is considerably greater in the postwar period than it was before the war. The trouble is this. While more people are at work, the tasks before us are now much broader. Investigations are steadily becoming more difficult and more expensive in many fields of physics. The disturbing fact is the small fraction of the total support which goes into fundamental research.

(1) Report of the Steelman Committee.

Late in 1947 the President's Scientific Research Board, usually called the Steelman Committee, made its report. This was the most complete attempt to survey American research which has ever been undertaken. Let us see what the Steelman Committee said. Table I shows the approximate funds devoted to basic research and to applied research and development.

TABLE I. THE NATIONAL RESEARCH AND DEVELOPMENT BUDGET - 1947.

In Millions of Dollars

Agency	Total	Expenditures of 1947: Basic Research	Applied Research and Development
Total	$1,160	$110	$1,050
Federal Government..	625	55	570
War and Navy	500	35	465
Others	125	20	105
Industry	450	10	440
University	45	35	10
Other	40	10	30

According to Table I, a billion dollars a year was at work in 1947. This is about one-half percent of our national income. The points to notice are, about one-half the total is represented by Federal support of research, and four-fifths of this half was devoted to research of the armed services. While the old-line government laboratories, outside the armed services, expanded during the war, their share was only a fifth of

the Federal research budget in 1947.

The expenditure of government was believed to outweigh the entire effort of industry. Of course, that depends on how you define research, development, and testing. These figures are just the best guess the Committee could make, after study of available facts. Notice now a significant fact. The expenditures by universities, foundations and state governments are so small that they are almost lost in Table I.

Observe, also, the relatively small part, about ten percent of the whole, which is spent on basic research.

The government laboratories cannot handle the jobs to be done. More than two-thirds of the Federal funds are spent through industry and through universities.

The Steelman report clearly states a fact we all know, that support from foundations and rich men is on the wane. The tax collector sees to that, and inflation has killed the dollar.

Government support for research in the universities falls into two broad classes, --grants and contracts.

The number of agencies with contracting authority in the fields of development and research is large. I have a list of about 40, and know that it is not complete. The Office of Naval Research has been closely concerned with the support of research in a variety of fields. Now the Army is doing the same through its Office of Ordnance Research, and the Air Force has a somewhat similar program. Fundamental research in the universities would be in sad shape without the funds provided by these agencies, and certainly a very fine job has been done. The original theory, when the Office of Naval Research was set up, was that it would give a shot in the arm to university research and that later the National Science Foundation would take over the job of supporting basic research, leaving the armed services with their proper job of handling defense research. It did not quite work out that way. There was difficulty in getting suitable legislation to establish the National Science Foundation. When the Foundation was set up, Congress proved to be very niggardly in appropriating funds. I hope that Dr. Klopsteg will give us a good picture of the Foundation's present program and its financial problems, during the course of these meetings, so I shall say no more on this point.

The Steelman Committee made recommendations for a National program of research support in 1947. The recommendations for the decade 1947-1957 are shown in Table II.

TABLE II. THE STEELMAN RECOMMENDATIONS.

(1) Double the National Research Expenditure Within 10 Years.

(2) Triple the Funds for Health, Medicine.

(3) Quadruple Funds for Fundamental Research.

(4) National Science Foundation.

(5) Federal Student Aid.

(6) Federal Assistance to Universities.

(7) Interagency Committee.

(8) Aid to European Laboratories.

The first point calls for doubling the research and development expenditure of the nation. That would make it two billion dollars. As a matter of fact, the National Science Foundation has just reported that in 1952 the total was 2.2 billion dollars. By 1954 it is expected to be slightly higher. How did they get this factor of two? It is not fully justified in the report, but apparently it rests on manpower. The Committee knew that existing problems outrun the capacity of our current stock of research and development people, estimated at 140,000 souls. They knew that training scientific manpower is slow business. They knew that Russia kept its students and professors in the schools and laboratories during World War II. In the Steelman report the hope was expressed that we could double our research manpower by 1957.

The plan calls for tripling the funds devoted to health and medicine in five years. Also, it calls for quadrupling the funds for fundamental research. Good; but maybe it is not enough.

The fifth point calls for Federal assistance to science students. Those who have taken part in government programs of instruction will appreciate the controversial nature of this item.

Point six calls for Federal assistance to provide for laboratories, and scientific equipment used in teaching. This would involve another surrender of states rights

and local rights.

The main point I want to make is that out of all this great expenditure the fraction earmarked for research of the pure and pioneering type is relatively small. I do not have an up-to-date figure, but believe it is practically certain that this fraction is smaller than it was in 1947, when the figure stood at about ten percent. It is only this ten percent from which you can expect great new results.

We can be quite sure that a great many physicists will play their parts in rendering useful practical services to industry and to government. All the economic factors work in that direction. However, any really big advances in fundamental physics will have to come out of studies which do not appear at the moment to be of any practical value. The National Science Foundation is set up for exactly this purpose, to try to insure a flow of new unexpected results, but its activity alone will not suffice to insure that physics and its sister sciences continue to make important contributions to national welfare. We must not look to Washington for everything. The basic support of university research has always been provided by the universities themselves. The amount of that support has been pitifully small in many instances. Many of the greatest discoveries which adorn the annals of Science have been made with meager funds and facilities. At the present time there is a job to be done in enlisting better support of scientific research by the individual states. This is a matter of high importance.

In closing, let me summarize the situation. It is not possible to order from a physicist, or any other scientist, a discovery that will significantly increase prosperity. You cannot order discoveries as you order articles in a store. This is the ultimate justification of long-haired academic research. Professors and students have to be allowed to play around. There must be time to think, time to play in the laboratory. Only in this way do unexpected and truly valuable fruits emerge, to increase the weal of the nation. Research is just another word for making something out of nothing. Let us work it to the limit.

Let me illustrate this with a little story about John D. Rockefeller, Senior.

When John was a little boy, a seller of patent medicine came to town in a big covered wagon. He was selling his medicine from the tailboard of the wagon, and little John was in the audience. Every once in a while, to keep up interest and draw the crowd, the medicine man would auction something off. He said, "Now, gentlemen, we will auction this brand-new dollar bill. What am I bid? Who will bid a quarter?" Not a man answered. Everybody was afraid the dollar bill was counterfeit. Each would nudge his neighbor and say, "You bid, Bill." "No, you bid, Jim. I' m not durn fool enough to bid." Finally, little John D. Rockefeller spoke up. "I bid a nickel, sir." "Fine," said the medicine man. "Who will better this little boy's bid? Surely you are not going to let this little boy take away this fine dollar bill for a measly five cents?" But the crowd would not bid, and the dollar went to John, "Going, going, gone! Here's your dollar bill, son. Where is your nickel?" Little John answered, "Please take it out of the dollar, sir!"

PROGRESS IN FOREST UTILIZATION*

By George A. Garratt
Dean, School of Forestry, Yale University

For more than three centuries, the products of our forests have played a major role in housing the American nation and in meeting the country's expanding industrial requirements. Despite the intensified present-day competition of concrete, steel, aluminum, plastics, and a variety of other materials, lumber still finds widespread application in residential, farm, and industrial construction, and in the manufacture of shipping containers, furniture, flooring, millwork, patterns, handles, and an extensive list of other secondary products. As the outstanding primary forest product, lumber accounted for 63 per cent of the more than 12 billion cubic feet of timber cut for conversion to commodities in 1950. Pulpwood absorbed 14 per cent of the timber cut, fuelwood 11 per cent and veneer logs 4 per cent, while the remaining 8 per cent was represented by such items as hewed railroad ties; poles, posts, piling, and mine timbers; and logs, bolts, and cordwood for manufacture to diversified products. In all, there are some 50,000 to 60,000 sawmills, approximately 650 veneer and plywood plants, and about 250 pulp mills in operation in the United States, supplemented by an even greater number of secondary manufacturing units that utilize the products of these primary mills. These primary and secondary manufacturing plants are estimated to produce goods with a gross annual value in excess of 15 billion dollars, and to provide direct and indirect employment for over 3 million people.

The commodities derived from its forests are a vital part of the economy of the South, producing an annual income of 2.3 billion dollars, or 7 per cent of the total income of the region derived from other than government payments. Of all of the southern states, Mississippi depends most heavily on its forest resource, with

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* A paper presented at the Research Symposium commemorating the Seventy-fifth Anniversary of Mississippi State College, April 24, 1953.

23 per cent of the 1946 income of its 2,100,000 people derived from raw timber products and their further manufacture.

The South has maintained a prominent position in American lumber production throughout the present century, the latest available statistics (1947) indicating the regional production as almost 37 per cent of the national total, as compared with 46 per cent for the western states. Even more significant is the South's contribution to American pulpwood production. In 1951, this reached an all-time high of 14 million cords, or 56 per cent of all the pulpwood cut in the United States, and accounted for 18 per cent of the total wood volume removed from the southern forests. The outstanding growth of the pulp and paper industry in the South is revealed by statistics on daily capacity, which increased from about 5,000 tons in 1936 to almost 23,000 tons in 1950, with a further expansion of 6,000 tons of pulping capacity under consideration.

Nature of the Timber Resource

While our forests represent our nation's one great renewable resource, three centuries of progressive exploitation have taken their toll in decreasing the amount and altering the character of our timber supply. The commercial forest land has shrunk to about two-thirds of its original area, and the amount of sawtimber to one-third of its earlier volume, as the original old-growth (virgin) forest has been largely replaced by second-growth stands. Today, more than half of our estimated sawtimber volume of 1,600 billion board feet is concentrated in about 45 million acres of virgin forest, chiefly in the West, a fact which focuses attention on the relatively small size and low volume of sawtimber on the second-growth areas occupying nine times the old-growth acreage.

This general transition from an old-growth to a second-growth forest economy has been accompanied by a deterioration of the residual timber stands, as the result of poor cutting practices and of destruction by fire, insects, disease, and other natural agencies. These have combined to leave some areas with few,

if any, trees of consequence, but many more stands with an excess of young trees and a predominance of low-grade timber and less desirable species in the sawtimber class. In many areas, also, the proportion of hardwood species is continually increasing at the expense of the currently more valuable softwoods. Recent Forest Survey figures for Mississippi, for example, indicate that 40 per cent of the sawtimber stands in the state contain only timber of the lowest grade; of a total of 17 billion board feet of hardwood sawtimber, 65 per cent is in grade 3 logs.

As a consequence of this change in the timber resource, a large proportion of our forest industries is today faced with shortages of the size, quality, and kind of timber which they were designed to use and which some of them must have if they are to survive. These shortages are frequently intensified by the increased competition among the various primary forest industries for supplies of available timber, and especially by the concentrated exploitation of favored species; in more than a few sections the problem of raw-material supply has been made especially acute by the installation of more sawmills and other wood-processing facilities than the forests can advantageously support. In many areas, of which Mississippi may be taken as an example, sustained harvesting of timber has been accomplished only by increased use of less desirable species and lower quality and smaller trees, and by increased production of pulpwood and perhaps other products with less exacting raw-material requirements.

The transition from virgin forest to second growth has been accompanied by a distinct shift in size of sawmills and certain other facilities processing forest products. With certain notable exceptions, the large mills, which formerly dominated the lumber-production field, have generally given way to small mills, better adapted to harvesting the prevailing small timber and light stands, and the remnants of denser stands, all too limited in timber volume to meet the requirements for economic operation of more sizable plants. Statistics indicate that small to moderate-sized sawmills (cutting less than 5 million board feet per year) constituted

almost 98 per cent of the total number of mills operating in the United States in 1947, and produced slightly more than 50 per cent of the lumber cut for that year. By way of contrast, in 1929, mills of these same size classes, while comprising 94 per cent of the total operating units, accounted for only about one-fourth of the U. S. lumber production.

The portable mills, which prevail throughout most of the eastern two-thirds of the United States and which generally saw out less than one million feet per year (5,000 feet per day), present a special problem. Such units either commonly saw for a restricted crosstie or dimension market with resultant waste of timber, or they produce chiefly rough lumber which all too often is a low-quality product, poorly manufactured, improperly seasoned, and inadequately graded, and marketed locally at a distinct competitive disadvantage with lumber manufactured at larger mills.

Still another significant change accompanying the general shift from an old-growth to a second-growth economy has been noted in the pattern of ownership of commercial forest land, with farmers and other small landowners dominating the situation. While approximately three-fourths of our 460,000,000 acres of commercial forest land is privately owned, it is held for the most part in relatively small blocks of less than 5,000 acres. Estimates for 1945 indicated that three-fourths of the private commercial forest land in the United States was then in such small ownerships, with an average of 62 acres per holding for an estimated four million owners. Farm woodlands throughout the eastern half of the United States constitute about 40 per cent of the total private land, and practically the same amount of timberland is in the possession of about a million small, nonfarm owners. Even in Washington and Oregon, which in 1947 produced 30 per cent of the nation's lumber cut, tracts of less than 5,000 acres account for almost 60 per cent of the forest lands in private ownership. Such small holdings present a difficult utilization problem, because the relatively small volume of merchantable timber

in each block tends to discourage conservative harvesting practices.

Of interest, in connection with this problem of size of timberland holdings, is a 1949 survey of small woodland owners in New England, made to determine their occupations and reasons for holding forest land. It was revealed not only that 96 per cent of the owners covered in the survey had occupations that did not involve the use of their woodlands for timber production, but that half of the properties (representing 40 per cent of the acreage) were held for reasons other than the value of the timber they contained.

Forest utilization in the United States is notoriously wasteful of raw material, it being estimated that only 43 per cent by weight of our timber harvest is converted into usable products, other than fuel. Under existing utilization practices, 35 per cent of the original wood finds no use whatsoever and the remaining 22 per cent is burned for fuel. Non-converted wood in 1944 was estimated at about 109 million tons, of which 45 per cent represented logs and other items left in the woods after logging, 41 per cent came from primary manufacturing, 8 per cent from pulping, and 6 per cent from secondary manufacturing operations. The actual amount of residual material, or waste, naturally varies with the industry, ranging from very slight in the production of such products as roofing felt (with utilization down to 2-inch tops) to quite high in the wood-turning industry, in which only 5 to 27 per cent of the cord which comes out of the woods finally ends up in toys, handles or spools.

Various uses are proposed for this residual material, but such practical limitations as the labor costs involved in handling the wood, transportation costs where it is necessary to move the material any distance to concentrate it at central conversion points, equipment costs, and other economic factors, as well as technological problems, combine to restrict the application of many of them. Nevertheless, definite progress is being made in the residual utilization field, fostered by the good markets of the past few years for various wood and pulp products.

A conspicuous example of effective utilization of residual material from primary manufacturing plants is recorded by the sulfate pulp mills in the Pacific Northwest, which derived 50 per cent of their 1951 wood requirements from sawmill waste and an additional 12 per cent from plywood-plant waste.

The problems of present-day forest utilization are fundamentally economic. Their solution is associated with such achievements as the development and appropriate application of new and improved methods for efficient harvesting and processing of the kind, size, and quality of timber now available, including the present large volume of logging and mill residuals or waste. Above all else, the solution of these problems is associated with the development of adequate markets for such conventional and new products as can be derived from these raw materials. To be effective and realistic, however, these developments must be aimed at improving the character and quality of the timber stand and effectively rebuilding our timber resource, fully as much as at obtaining needed wood volume.

The primary purpose of this paper is to consider a limited number of the more recent technological advances in the field of forest utilization and to point up their potential contribution to the solution of our present forestry problem. Not the least important of these advances are those which can make effective use of previously unwanted species and unused residual material.

Timber Harvesting and Processing

The lumber and associated wood-using industries have been faced for some years with certain economic and technical limitations associated with such factors as inadequate supplies of quality timber, high wage scales and shortages of skilled labor, general inefficiency of harvesting and milling equipment and techniques, prevailing lack of seasoning facilities and shortcomings of grading practices, and inability to maintain and develop suitable and profitable product outlets. Furthermore, the predominant small independent sawmills and other individual wood-using plants in most sections of the country have shown general inability to obtain the

technical services necessary to overcome the existing harvesting, processing, and marketing difficulties. In recent years, however, and particularly since the war, some of the larger industrial units and a number of private organizations and government agencies have been attacking these several problems on a cooperative basis, and distinct progress is being made in improving timber harvesting and the processing of lumber and other primary and secondary wood products.

Developments in Logging

The introduction of mechanical equipment in woods operations has been a significant factor in increasing labor efficiency and thereby making economically available many areas that could not be logged profitably under earlier methods. The flexibility of harvesting operations has been notably increased by tractor logging and truck transportation, which have made it possible to operate on small tracts and in lightly stocked stands. The ability of the operator to make frequent and economical moves with the newer mobile equipment has definitely increased the opportunity for utilization of timber now wasted and for the application of good forestry practices. The harvesting of small second-growth timber and of trees cut in thinning operations has been facilitated by the use of portable power saws, special systems for bunching and skidding tree-length logs, improved loading devices, and such new developments as pre-loading of trailers, the use of pallets, and bundling of short-length material, all designed to increase the efficiency of harvesting and thereby reduce its cost.

Developments in Milling.

The recognized shortcomings of many lumber-manufacturing operations, and notably of the portable and other small sawmills, have emphasized the need for improving basic sawmill design, devising more adequate sawmill and woodworking equipment, revamping processing techniques, and training good sawmill operators. They also indicate the necessity for providing adequate facilities for proper seasoning, finishing, grading, and marketing of lumber, if not at individual

small mills at least at concentration yards or other integrated milling units. Distinct progress is being made in all these aspects of lumbering.

A notable recent development in the production of lumber is the barking of logs before sawing, to provide residual material suitable for direct conversion to bark-free products. The slabs and edgings obtained from unbarked logs find limited use for remanufacture into such items as dimension stock, box boards, handle stock, and dowels, but more often such combinations of bark and wood are suitable only for fuel or a disposal bonfire. In contrast, bark-free wood is finding increasing use as a source of chips for the manufacture of pulp. It is also stated that the barking of sawlogs has been found to increase lumber yields by as much as 10 per cent, as well as increasing the amount of top quality lumber obtained.

Integrated Utilization

Increased attention is being devoted to integrated utilization, which has as its objective not one-product but rather multiple-product harvesting on a single logging operation. Under such a system the individual species and log qualities being harvested are distributed among the industries concerned on the basis of suitability for most effective use. Thus, logging is carried out not for a single class of material, such as high-grade veneer logs, but also for the purpose of obtaining saw-logs, turning bolts, pulpwood, or other products for which there is a continuous demand. Such procedure may lead to definite economics in the logging operation itself, as well as effecting more complete utilization of the timber stand being cut, thereby bringing greater financial return to both the landowner and the operator.

A recent report*, referring to conditions in Mississippi, points to the opportunity of utilizing for pulpwood the tree tops commonly left in the woods in pine sawlog operations; it is estimated that a year's accumulation of usable pine

* U. S. Forest Service: Mississippi Forest Resources and Industries, Forest Resources Report No. 4, 1951

tops is equivalent to about 20 per cent of the present pulpwood production in the state. Hardwood utilization can also be extended by integrating the harvesting of sawlogs and veneer logs with the production of smaller tie logs and slack cooperate bolts.

Glued Wood Products

Outstanding among the recent developments in the field of wood use have been the advances made in the production of a wide variety of glued-up products, including laminated forms of wood, plywood in flat and molded forms, and composite products, such as "sandwich" materials and other combinations involving the bonding of dense woods, metals, or other materials to normal-wood or low density cores.

Particular significance is attached to recent developments in the field of adhesives, and especially to the introduction in the 1930s of the first synthetic-resin glues, which extended the practical use of glued-wood products to outdoor and other exposed situations. World War II was marked by accelerated improvements in the adhesives field, involving the application of the original phenol and urea glues to the most exacting military uses (such as aircraft and naval-craft construction), the introduction of new types of resin adhesives with varying properties and uses (resorcinol, phenoresorcinol, and melamine glues), and the improvement of techniques for applying and setting the adhesives. Included among the advances has been the development of glues for bonding wood to metal and to various plastic materials. Continuing research is aimed at the development of universal adhesives which will combine quick-setting properties at low temperatures with high strength and water-proof features, to produce low-cost plywood and laminated products suitable for interior and exterior use under all types of exposure.

Laminated Wood

A major impetus to the use of wood has been afforded by the development of adhesives and techniques for bonding together boards or other relatively small pieces of wood to form laminated units, ranging from large, straight or curved

structural members to relatively small pieces suitable for the production of various turned articles. Laminated structural members, such as beams, columns, arches, trusses, and rafters, prefabricated at the factory and assembled on the job, have essentially the same properties as solid wood, but are no longer restricted in size to the dimensions of the logs from which solid timbers can be cut, or limited to the conventional shapes and curvatures of such solid units. Furthermore, their design often makes possible the use of a significant percentage of low-grade or short-length pieces in the interior, lower-stressed laminations of beams and arches, and thus provides for more efficient use of wood. Laminating is of special advantage in the utilization of logs from second-growth timber and of mill waste. An added advantage of such processing lies in the relatively rapid and efficient seasoning of the thin component laminae, which makes it possible to produce large or small laminated items, dried to the desired moisture condition and free from serious checks and other seasoning defects.

At the outset, the use of laminated structural timbers was limited largely to interior construction, notably as roof arches in recreational halls, churches, theaters, factories, and other buildings in which it was desired to have wide floor areas unimpeded by supporting columns. But, during World War II, the development of waterproof adhesives made it possible to utilize laminated members for keels, frames, and other timbers in the construction of small naval craft; our present shipbuilding program gives high priority to wooden vessels of non-magnetic laminated design for minesweepers and patrol, landing, salvage, and rescue craft. The development of these waterproof adhesives and of new glue-setting techniques has further extended the use of laminated structural timbers to various types of other outdoor construction.

Laminated wood also has wide application in the manufacture of automobile and truck bodies, airplane parts, furniture, sporting goods, shoe lasts, agricultural implements, ironing boards, and many other items. Within the past few weeks, several

prototypes of all-wood truck bodies, designed to withstand all types of exposure and service, have been placed under road tests by the Army Ordnance Corps. These are built of U-shaped, one-piece, laminated frame members, which combine the functions of bolsters and side supports and obviate the need for any mechanical joint between bottom and sides. To them are fastened floor and side panels made of either "stressed-skin" plywood or edge-glued solid wood sections. Still another experimental product now under study is the laminated railroad tie, made with a dense hardwood bearing surface glued to a softwood core.

Plywood

Conspicuous among the recent advances in wood utilization are those in the manufacture and use of plywood, which during the period between the two world wars was in constantly increasing demand for both industrial and architectural purposes. However, its use during that time was largely restricted to interior construction and to temporary exterior applications in which the relatively low water-resistance of the glue was not a distinct disadvantage. In contrast, the more recent development of the new and improved adhesives has now converted plywood to an item of practically universal application, not only in flat panel form, but molded to various curved shapes as well. The demonstrated success of the new plywoods in the construction of the Mosquito bomber, troop-carrying gliders and trainer planes, the torpedo-carrying PT boat, and numerous other wartime structures brought widespread recognition of their obvious utility for the demands of the postwar era. Recent statistics (1948) indicate that 40 per cent of current plywood use is for various purposes in house construction, 15 per cent for heavy construction, and 45 per cent for industrial uses, including packaging, furniture and luggage, millwork and doors, and railroad, automotive and maring applications.

One of the outstanding achievements in plywood utilization has been the development of unit, or prefabricated, construction particularly designed for housing. Such construction had its inception some years before World War II,

but was restricted in its more favorable application until the introduction of a suitable moisture-resistant plywood. During the war years the acute need for living accommodations in crowded industrial communities and at military establishments so stimulated the demand for homes that many thousands of housing units were built of factory-made plywood-panel walls, floors, ceilings, and partitions. Each year since World War II the industry has expanded its operations, with 1952 production expected to exceed 55,000 prefabricated units and to account for approximately 8 per cent of all new, single-family houses built in that year. Today, there are about 50 prefabricated home manufacturers, distributing their products chiefly through some 3,000 local dealer-builders in 40 states.

The construction of floor, wall, and roof panels for prefabricated buildings is based on the "stressed skin" principle, in which plywood facing is glued to the interior studs or stringers in such a way that all components contribute directly to the strength of the structure. This same stressed-skin design, with plywood glued to laminated wood supports, is being applied in the construction of highway trailers and railroad box cars.

The production of curved shapes, or molded plywood, is another of the major advances in the plywood field. The adaptation of improved synthetic-resin adhesives to new processes, such as bag or fluid-pressure molding, has made possible the rapid and extensive manufacture of parts having pronounced and compound curvatures which could not satisfactorily be attained by other available methods. Molded plywood found rather wide use in the marine and aircraft fields during the war and now has extensive potential application in the manufacture of such items as aircraft units, canoes, small boats, light-weight truck and station-wagon bodies, radio cabinets, furniture, and a wide variety of novelty products.

The need for continual produce development in the forest industries is typified by some of the recent activities in the Douglas-fir plywood field, where the scarcity of high-grade peeler logs coupled with a decided increase in plant

capacity has led to certain adjustments in processing, to permit use of logs of poorer quality and smaller size. Thus, improved processes for patching open defects and for edge-gluing narrow sheets of veneer have made it practical to supplement the supply of peeler logs with sawmill grades of logs and thereby maintain plywood production. Masking overlays of resin-impregnated paper are also being applied to plywood surfaces for the purpose of hiding blemishes in the lower-grade face veneer. Actually, such plastic overlays are finding increased use, not only as a means of upgrading plywood by masking minor defects, but also by imparting special characteristi to the surface of the wood. Thus, they may take the form of a sheet of decorative paper, intended to provide an attractive surface that is also resistant to abrasion and to liquid absorption, or be in the nature of a high-density surface laminate that increases the strength and rigidity of the plywood, as well as its resistance to wear and water absorption. The greatest single present use for plastic-overlay plywood is for concrete forms, where it is used to impart a smooth finish to the concrete; the plastic surface can be readily cleaned, thus making possible the repeated use of the plywood forms.

The recently developed "sandwich" materials represent a composite construction in which low-density woods, pulpboard, or other light-weight cores of appreciable thickness are surfaced on both sides with thin sheets of relatively high-density, strong, durable materials, such as plywood or resin-impregnated compressed wood or paper. The outstanding wartime use of this type of material was in the Mosquito bomber, in which the gluing of birch plywood faces to a low-density balsa-wood core afforded a light-weight construction of considerable thickness, relatively high strength, and very high stiffness. Among the more recent developments in connection with this product is the use of a resin-impregnated paper to form an open honeycomb type of core. "Sandwich" materials are currently finding use where light weight and high strength are important, as in aircraft construction. The insulating and sound-deadening properties of the low-density core also suggest the use of "sandwic

construction for doors and exterior wall and roof panels in buildings, as well as for refrigeration units.

The wartime development of adhesives for bonding metals and plastics to wood is also finding application in the fabrication of composite products. This is especially significant in the opportunities afforded for using appropriate metals and alloys, plastics, and plywood in combination rather than as replacements for one another. These combinations afford constructions and uses that take advantage of the best qualities and properties of each material for a given purpose and provide items superior to those made of one material alone. Opportunities appear especially promising for the use of metal-faced plywood and solid wood in making aircraft parts, automobile bodies, railroad cars, furniture, road signs, and store fronts. Fiberglass, cloth, paper-base plastic, and other materials are currently under development for bonding to plywood to achieve desired surface characteristics, as well as to conceal defects in the wood. Such materials have definite possibilities for improving the appearance and serviceability of low and medium-grade plywood and hardboards.

Preservative and Fire-Resistant Treatments

Research in recent years has resulted in distinct advances in methods of treating wood to increase its serviceability. Outstanding among the improved processing methods are those concerned with wood preservation and fire-resistant treatments.

Notable results have been obtained in developing chemicals and processes for increasing the resistance of wood to deterioration by decay, termites, marine borers, and other agencies. The application of wood preservation has been especially significant, not only in increasing the service life and thereby decreasing the ultimate cost of various types of wood construction, but also in making available for use species of wood that would otherwise be unacceptable because of their rapid deterioration when used in contact with the ground or in other exposed situations. Continued improvements are to be expected, in the development of new chemicals and

improved processes which will result in increased serviceability and lowered costs of treated products. The use of chlorinated phenols and other oil-soluble preservativ together with such comparatively simple methods of application as cold soaking and barrel treatments, is among the recent developments. While wood preservation has been widely adopted by the railroads and other large industrial users of structural forms of wood, a major field of opportunity lies in extending the use of treated wood in residential and agricultural construction and in other fields that immediately concern the consumers of small to moderate amounts of wood.

Considerable impetus was given, during the war period, to the development of fire-resistant treatments for wood. Federal specifications for flame-proofed lumber and plywood were adopted by the Army and Navy to meet military requirements for a variety of products and types of construction, and these materials have also been incorporated in railroad structures, hotels, hospitals, and theaters, as well as in industrial and commercial buildings and other structures in which the fire hazard is relatively high. The chemicals and methods used in processing fire-resistant wood are costly, however, and definitely preclude the extensive use of such treated material in the general construction field. That must necessarily await the development of less expensive, but equally effective, treatments.

Chemical and Mechanical Conversion

Much attention is being devoted to extension of facilities for the chemical and mechanical conversion of wood. This development has particular significance in forest utilization, because of the adaptability of such processes to logging and milling residues, to low-grade timber and little-used species, and to the type of material which may be harvested in thinnings and improvement cuttings in both hardwood and softwood stands. Knowledge in this field has advanced to the point that the immediate problems of application are, to a considerable degree, economic rather than technological. Outstanding among these conversion outlets is the producti of pulp and paper, but considerable activity is also being shown in the manufacture

of insulating boards and hardboards and of roofing felts and other building papers, in charcoal production, and in other processing methods which can utilize the indicated classes of timber.

Pulp and Paper

Among the most notable technological advances in wood utilization in recent years have been those in the pulp and paper field, as related to methods of reducing wood to pulp and to the development of new products. Such advances have been stimulated by the expanding markets for various types of papers, paperboards, insulating boards, textile fibers, and other cellulose-base products. Illustrative of the increased demand for wood pulp is the current expansion in use of paperboard containers for milk and frozen foods and other products of the mass-production food processing industry. Another area of expanding use is that of papers and boards for building construction, including insulating materials and absorbent felts for roofing.

The problem of supplying the pulpwood requirements of the expanding paper and paperboard industry is being solved in the main by increasing the raw material base, to include the use of significant quantities of hardwood species, of small and low-grade softwood logs, and of logging and sawmill residues. A second line of approach to the problem of increasing the amount of available pulp has involved the development of modified chemical processes that increase pulp yields and thus decrease the amount of wood required to produce a ton of pulp or paper.

In the search for pulp yields higher than the 45 to 50 per cent of the original weight of wood obtained with the conventional sulfite, sulfate, and soda processes, two general pulping procedures have been devised, both involving a mild chemical treatment of wood chips, followed by mechanical refining to accomplish separation of the fibers. One of these methods, the so-called high-yield sulphite and sulphate pulping, is limited in its application to softwoods and provides yields up to 60 per cent of the original weight of wood. The second method, designated

as semichemical pulping, is particularly well adapted to reducing hardwoods and gives yields of 65 to 80 per cent or more (up to 90 per cent in the recently developed cold soda process).

Semichemical pulping, with its twin advantages of applicability to hardwood species and high yields, has had a particular appeal to the pulp and paper industry and the adoption of the process has been quite outstanding. Beginning with the first commercial installation in Tennessee in 1925, the number of semichemical mills has now grown to 26; daily production capacity has increased almost sixfold over an 11-year period, from 465 tons in 1941 to 2,750 tons in 1951. Although employed mainly in the manufacture of corrugating board, the semichemical pulps are also finding use for both coarse and fine papers and in specialty boards.

One of the most recent developments of the pulping of wood is the chemiground process, which produces a pulp rather similar to the semichemical product, with yields of about 85 per cent of the original weight of wood. The chemiground method is essentially the mechanical or groundwood process, but applied to hardwoods which have been given a preliminary chemical treatment, with resultant upgrading of pulp quality. One company in New England has announced plans for construction of a mill to make hardwood pulp for newspring paper by the chemiground process. This plant is expected to produce 120,000 tons of newspring paper annually from formerly unused hardwood timber.

Hardboard

One aspect of new product development that is marked by continued expansion is the production of fiberboards from wood pulp. These products run the gamut from semi-rigid and rigid insulating boards (sp.gr. 0.02 to 0.40) to hardboards (0.30 to 1.15) and superhardboards (1.35 to 1.45), with particularly heightened interest in the denser products. The early hardboard (or pressed board) industry was dominated for about 20 years by one southern manufacturer, but in the past five years there has been a sharp expansion in production, from the $2\frac{1}{2}$ million

square feet (equivalent to 1/8" thick board) produced by 3 mills in 1948 to an anticipated production of almost 6 million square feet by the 16 mills operating in 1953.

The bulk of the hardboards produced today are made from fiberized wood or pulp which is formed into a mat of the desired thickness by one of several processes, and then compressed in a hot press to an essentially homogeneous sheet of the desired density (sp. ft. at least 0.80). Synthetic resin binders are added in some cases to consolidate the fibers in the board, while in other processes the hydrolysis and plasticising of the wood elements accomplish the same result. A somewhat different type of hardboard, currently receiving increased attention, is represented by the so-called "particle boards," made from such materials as sawdust, shavings, and other millwork residues, or from veneer clippings. These wood fragments, reduced to desired size, are coated with a synthetic resin adhesive, formed into boards, and then hot pressed to cure the resin and obtain the desired densification of the product.

The fibrous hardboards may have synthetic resins or drying oils added during manufacture to give greater strength, stability, or water resistance; dyes may be incorporated to give colored or black boards; and the surface may be embossed to simulate the appearance of leather, ceramic tile, or other material. Among the varied uses of hardboard are interior and exterior wallboard; panels, liners, and partitions in truck, bus and trailer bodies; furniture, cabinet parts and household furnishings; advertising displays, signs, and toys; templets and jigs for manufacturing operations; and facing for concrete forms. Several plywood mills are now manufacturing hardboard-faced plywood.

Extraction and Distillation

In contrast to the expansion in the pulp and paper and hardboard fields, the commercial extraction and distillation industries have been faced with serious economic problems which have limited their extension. Profitable extraction processes

have been largely confined to limited production of tannins, essential oils, and other specialty products, and to obtaining naval stores from resinous southern pine stumps; some $1\frac{1}{2}$ million tons of pine stumps were extracted in 1947, yielding 12 million gallons of turpentine and 3/4 million barrels of rosin. However, there are possibilities of obtaining other valuable extractives from wood, and these are under study.

The wood-distillation industry has been seriously affected in recent years by problems of raw material supply and of declining markets due to the competition of cheaper synthetic chemicals, such as methanol and acetic acid. In consequence, production has diminished to the point that the demand for charcoal has not been generally satisfied. This situation has resulted in revived interest in charcoal production in some areas, not only for the purpose of meeting the unsatisfied demand, but also of converting otherwise unmerchantable or low-value timber into a product which might be expected to bring at least a moderate return to the small landowner. This development has centered largely around the design of suitable portable and semi-portable kilns of relatively small size, with the objective of keeping the cost of transporting wood from stump to kiln at a low figure. However, further research is needed on the economics of production and on problems of marketing charcoal. Attention is also being devoted to the development of new distillation methods that may result in the production of other than conventional chemical products.

Multiple-Use Aspects of Forest Use

While this discussion has dealt with our forests solely from the point of view of their significance as sources of wood for conversion to consumer products, it should not be brought to a close without mentioning the other important services these timberlands are rendering in our national economy. The whole problem of multiple-use of our forests has grown in significance as it relates to watershed protection, wildlife conservation, grazing, soil conservation, and recreation.

Among the significant features of multiple use is the fact that these uses, other than forest products utilization, may be adequately supported by forests whose volume and composition at present are below reasonable standards for the production of sawlogs and other valuable wood products.

In this connection, it should be emphasized that, in general, there is no serious conflict between intensive management of forests for production of wood and the best management for multiple use. In fact, these other uses may serve to justify the cost of such cultural measures as may be necessary to restore depleted timberlands to the point that they can contribute more adequately to the wood requirements of the nation.

INDUSTRIAL CHEMICAL RESEARCH

By Dr. Frank J. Soday

Research is a scientific discipline that enables man to probe the secrets of nature in a systematic manner, thus leading to a better understanding of the physical world in which he lives. As an industrial tool, it is a development of the present century, and only within the past two or three decades has the industrial research laboratory become an indespensible part of our economy.

In assessing the value of research, one should not lose sight of the inherent inquisitive nature of man, which has led to notable advances in the past. Methods for the manufacture of iron were developed in prehistoric times, and the manufacture of fine glassware and exquisitely colored glazes was an established industry in the Nile valley some 5000 years ago. It is apparent, however, that these discoveries were made by the trial and error method of the untrained inventor, and by the patient refinement of known procedures, rather than by the application of scientific principles. As in the case of flint working techniques employed by primitive tribes, a certain mystery surrounded each occupation and no attempt was made to study the principles involved or to make use of knowledge acquired in one field to improve another.

Modern industry, as contrastered with primitive industry, had its origin in the industrial revolution set in motion in England in 1780 with the development of Watt's steam engine, the first practical device for converting heat into mechanical energy. The invention of the spinning jenny by Hargreaves in 1764 and the automatic power loom by Cartwright in 1785 transformed the manufacture of cloth from a cottage industry to an industrial enterprise. Villages became factory towns, and these in turn became cities. This growing industrial power enabled England to rapidly become a world empire.

The industrial revolution was only one aspect of this age of ferment. Western man was recovering from the intellectual stagnation of the Dark Ages, and his

awakened curiosity was exploring the whole area of human endeavor. In the political field, this was to lead to the development of democratic principles that would result in the abolition of autocratic rule in many countries. In the physical world, his increasing knowledge of scientific principles would eventually result in broadening the horizons of science and technology.

At the beginning of the industrial revolution, technological advances had little to do with science. Although Watt was led to undertake his experiments on the steam engine through his knowledge of basic studies being carried out by others in the field of calorimetry, he was an inventor rather than a scientist. This pattern of parallel, but not cooperative, effort on the part of the inventor and the scientist was followed until the beginning of the present century.

Under the leadership of Berzelius, Lavoisier, Wohler, and others the alchemy of the Middle Ages was gradually transformed into the science of chemistry. This work was carried out mainly in academic laboratories by men dedicated to the field of science. The schools became the sole source of fundamental knowledge.

The scientific discoveries resulting from academic research slowly diffused into industry in a variety of ways. The publication of scientific data often acted as a stimulus to the practical inventor, resulting in important advances in many industrial operations. In certain cases, the academic scientist would become so impressed with the practical possibilities of his fundamental discoveries that he would seek an industrial position in order more fully to exploit them. A few organizations also made use of the scholastic scientist in a consulting capacity, although this arrangement was not too satisfactory in most cases due to a lack of knowledge of the scientific method on the part of industry. While scientific research was making increasingly important contributions to industrail progress, research was not a recognized industrial activity.

The Growth of Industrial Research

At the turn of the century, a number of progressive companies recognized

that industrial progress had become increasingly dependent upon the use of fundamental knowledge accumulated through generations of academic and private research in scientific fields. In order to take full advantage of the possibilities of improving their operations by the use of such knowledge they began to establish research laboratories within their own organizations. This partnership between science and industry proved to be so profitable that research was soon regarded as an essential operation in industry.

The rate of growth of industrial research laboratories during the past quarter of a century, both with respect to the number of such laboratories and the magnitude of their operations, has been nothing short of spectacular. A recent survey by the National Research Council indicates that 2800 industrial organizations in this country operate more than 3300 research laboratories. Every one of America's 100 largest industrial corporations maintains at least one research laboratory, and some, like DuPont, have several. In the latter case, research laboratories concentrating on a particular phase of the company's activity are located at various places throughout the country, usually adjacent to a place concerned with that activity, with a central research laboratory to work on fundamental problems and to coordinate the efforts of the more specialized laboratories.

Industrial research is carried out in three ways, namely, (1) by industrially owned and operated laboratories, (2) by industrial research institutes, and (3) by industrially supported academic research. The largest volume of industrial research is carried out in company laboratories, which is the most desirable method when the business is large enough to justify the necessary investment and operating costs.

The industrial research institutes offer a research service to industry on a fee or other basis. It provides an effective method for conducting research when a business is unable to supply its own facilities, or where the nature of the project requires specialized equipment or skills not available in the company

laboratory. Some were established early in the century, such as Arthur D. Little in Boston, while others are of more recent vintage, such as the Southern Research Institute in Birmingham and the Southwest Research Institute at San Antonio.

Industrially supported research in colleges and universities was started before the advent of the industrial research laboratory, and many important industrial advances were conceived and nurtured in this manner. This procedure is steadily growing in importance as many far-seeing business men recognize that it operates to the mutual advantage of both parties. While making fundamental data and research talent available to industry, it furnishes financial support to the educational institute, and serves to acquaint academic scientists with industrial problems and procedures. A number of chemical companies, ranging from the largest to some of the smallest, systematically sponsor research in the schools, and in many cases this sponsorship has been maintained for a quarter of a century or more.

A fourth type of industrial research is that conducted by the government. This is carried out in government laboratories, by grants to schools and colleges, and, in more recent years, by contracts with industrial organizations. While the majority of this research is, of necessity, tied into our defense effort, some government funds are available for other purposes. About $10 million of federal government funds will be available this year for basic chemical research in the schools.

The relationship between science and industry can be measured by the magnitude of research supported by industry and by the rate of growth of industrial research over the past quarter of a century.

The total expenditure for research and development in this country in 1952 was $3.5 billion, of which industry spent nearly $2 billion. Thus, the nation is spending approximately one per cent of its income on research.

The chemical, aircraft, and electrical industries accounted for 55% of the total spent on industrial research. The average industrial company spent 2% of

the total value of sales and services for research, while the chemical industry spent 2.5%. Some of the larger chemical companies spent 3¢ out of each sales dollar to support research. The average cost per industrial researcher was $22,000. A total of 94,000 scientists and engineers was employed in industrial research laboratories, together with 140,000 assistants, technicians and administrative personnel. This is more than twice the number employed in 1940 and more than 10 times the number employed 25 years ago.

Industrial research is being hampered by a lack of properly trained technical personnel to conduct its operations. It is estimated that industry could absorb 50,000 chemists and engineers for technical work in general this year, and that a continuing supply of 30,000 new graduates will be required each year. Only a fraction of this number will be available.

There are more than 160 industrial research laboratories in the South, as well as 40 well staffed and well equipped industrial research institutes. A total of 103 new laboratories, or major additions thereto, was established in the southern states last year, a rate of growth exceeding that of any other section of the country.

A total of 11,000 professional chemists are employed in the South. Texas leads with 2000, followed by Maryland (1700), and Tennessee (1400). The majority are employed in the chemical manufacturing industry (1700), followed by educational institutions (1600), and government laboratories (1500). Membership in the American Chemical Society is growing more rapidly in the South than in any other area, 48% in the last 5 years compared with 31% for the rest of the country. This is but a reflection of the rapid growth of industry in the South, which is setting the pace for the rest of the nation.

<u>The Need for Increased Academic Research</u>

As industrial research is concerned largely with the application of known scientific principles to the solution of practical problems, the industrial laboratories

draw heavily upon the stockpile of basic scientific data slowly accumulated through several generations of academic research. Practically every major development of this generation has its roots in fundamental studies carried out in the past in various college and university laboratories. One need only recall the developments in the fields of atomic energy, synthetic rubber, synthetic fibers, plastics, and pharmaceuticals, to name a few, to realize the extent to which industry is indebted to academic research for new processes and products.

Due to the phenomenal growth of industrial research during the past quarter of a century, many responsible scientific leaders are of the opinion that we have depleted our stockpile of fundamental data to the point at which determined efforts must now be made to replenish it in order to prevent the curve of technological progress from leveling off. While a certain amount of pure research is carried out in some of the larger industrial laboratories, it is unrealistic to expect that this will be sufficient to supply industry with all of the fundamental data which it must have. This is clearly the function of academic research.

It is industry's responsibility to see that adequate funds are available for the support of pure research in such laboratories. Some of this financial aid can come from the government and, as pointed out previously, approximately $10 million will be available for this purpose this year. But unless we are willing to permit fundamental research to be politically controlled, it will be necessary to contribute more generously to academic research than in the past. To do otherwise would result in the fountainhead of industrial research drying up at the source.

Fortunately, industry is fully cognizant of its stake in a continuing supply of this essential raw material, and is evaluating a number of proposals for supporting academic research. In the meantime, individual companies and manufacturing associations have largely increased the number of scholarships, fellowships, and research grants to the colleges and universities throughout

the country. A fertile field for further aid in this direction lies in the 30,000 companies having incomes in the range of \$2 to \$3 million, but possessing no research facilities.

The Chemical Industry

Many modern industries, such as the chemical industry, the electrical industry, the rubber industry, and the auto industry, owe their existence, in whole or in large part, to research. This is particularly true of the chemical industry.

In the rapid growth of industry in the United States during the present century, nothing can compare in speed and magnitude with the rise of the chemical industry. A product of research, it has expanded three times faster than the rest of the industry and has become the keystone of our economy.

In its development, it has transformed our way of life. Today, the average American lives largely on chemically nurtured and processed foods, dresses in clothing derived from synthetic fibers or chemically processed natural fibers, washes with synthetic detergents, and travels on synthetic rubber tires. It has developed whole new industries, such as synthetic rubber, synthetic plastics, synthetic fibers, and antibiotics, and has basically altered other industries, such as the protective coating industry. Conceived in the laboratory and nurtured by well-planned and well-executed research, it continues to set new expansion goals for industry.

The total value of the output of all of the chemical process industries was \$52 billion in 1952, practically unchanged from 1951. Nearly \$3 billion was spent on new plants and facilities.

Sulfur has been a reliable indicator of the business barometer, the 1952 production of 6.4 million long tons being essentially the same as that of 1951. New production facilities both from sulfur domes and from by-product sources, ended the threatened sulfur shortage of the previous year.

Chlorine production averaged about 7,000 tons per day, approximately the same as 1951. While the production capacity has been growing at the rate of 12%

per year for the past 20 years, there are some indications that it may be leveling off.

The total capacity for elemental phosphorus production is 285,000 tons annually, 70% more than 1951. Phosphoric acid production was 2 million tons. Organic phosphate usage is climbing rapidly.

Synthetic detergents continued to undermine the soap market, the 1952 production being 1.7 billion pounds compared with 1.4 in 1951. Soap dropped from 2.4 to 2.3 billion pounds.

Fertilizer production was 22 million tons. Nitrogen production was 1.4 million tons (N), potash 1.6 million tons (K_2O), and phosphoric acid 2.2 million tons (P_2O_5).

Plastics continued to grow, the 1952 production being 2.6 billion pounds compared with 2.4 billion pounds in 1951.

Synthetic fiber production was 250 million pounds, up 15% above the 1951 production of 210 million pounds. Rayon and acetate production was 1.136 million pounds, 12% less than 1951.

Production in the drug and pharmaceutical industry was 73 million pounds of undiluted medicinals, unchanged from 1951. Total sales dropped to $450 million from 1951's record $503 million. The total retail sales of all ethicals was $1.1 billion.

Production of fats and oils was 12.2 billion pounds compared with 8.5 billion pounds in 1951.

<u>Southern Chemical Industry</u>

The South continued to set the pace for the rest of the nation. Mr. McCormick, president of the American Stock Exchange, recently singled out the South as "the bellwether in a renaissance of industrial expansion and diversification in the United States." For the past two years, an average of one new multi-million dollar plant has started operations each working day. The South now has a total of 12,500

manufacturing plants employing 50 or more workers.

And nowhere has this expansion been more evident than in the chemical industry. Already possessing more than its proportionate share of the chemical industry of the country, the South has received nearly one-half of all of the new chemical plants approved for construction by the government. Ten of the 12 major plants built since the war by DuPont, the world's largest chemical company, are in the South, giving the company 20 large plants in 9 southern states. The South produces 90% of the chemical intermediates for the plastic industry and 90% of the nation's synthetic rubber. In the southeast, industrial growth and development is being paced by the rapidly growing textile and synthetic fiber industry. Nearly 80% of the rayon and acetate production is in the South, and practically all of the synthetic fiber industry is in the same area.

The petrochemical industry is almost wholly a southern industry, 85% of the petrochemical plants in the country being located along the Texas-Louisiana Gulf Coast. It is the most rapidly growing section of the chemical industry and today accounts for more than 25% of all of the chemicals produced in the country. It is expected that this will increase to 50% within 10 years.

Petrochemical production in 1952 was estimated at over 17 billion pounds, and petrochemicals now account for over 70% of all organic chemical production. The total investment in petrochemicals is over $2 billion.

In a recent survey of the southern chemical industry by the New York Times, Mississippi was stated to be "one of the best chemical growth areas in the region." While it ranks last in current chemical employment among 14 southern states, it is eighth in the order of new chemical plant installations. Its futrure possibilities are based on its natural resources and its position as one of the richest agricultural areas in the country. It now ranks ninth among the oil producing states in the country, with 2000 oil and gas wells.

It is interesting to note that Mississippi was the first state to be affected

by the growing power of chemical research. Madder, from which the dye indigo was obtained, was for many years the principal agricultural product of Mississippi. The brilliant researches of Sir Henry Perkin in England in the middle of the last century led to the development of a whole spectrum of dyestuffs from coal tar, thus freeing man from his dependence upon the soil for dyes and revolutionizing the industry. The cultivation of madder and other dye producing plants disappeared almost overnight.

Products of Industrial Chemical Research

In a survey made some two years ago by Life, it was found that the average family in this country owns some 10,000 different objects. A recent survey by the Journal of Commerce shows that each person uses 18 tons of materials per year, distributed as follows:

Fuel	14,000 pounds
Building materials	10,000 pounds
Ores	5,000 pounds (800 # of metal)
Fiber, pulpwood and other agricultural products	4,100 pounds
Food	1,600 pounds
Non-metallic materials	800 pounds

The man who retires at 65 will have used 1,170 tons or 2,340,000 pounds of materials. The provision of these materials is one of the major responsibilities of industrial chemical research. A few examples will be given to illustrate the manner in which research carries out this assignment.

A. Synthetic Rubber

During World War II, the Japanese were able to cut off 90% of the world's supply of natural rubber. Without ample supplies of this strategic material, the United States would not have been able to prosecute the war and would have been compelled to sue for peace.

Fortunately, a large amount of fundamental data concerning the preparation of synthetic rubber had been accumulated as a result of academic research extending back nearly 100 years. In the 1920's, the DuPont Company started an investigation which was to lead to the development of neoprene, the first true synthetic rubber. Other companies, both here and abroad, became interested in the project and a growing synthetic rubber industry was well established in this country prior to Pearl Harbor.

Stimulated by the demands of war, the government constructed a $1 billion dollar synthetic rubber industry with a capacity of one million long tons of rubber per year in the short space of 2 years. The production of synthetic rubber continued after the war and is now an integral part of our national economy. Without this continuing supply of rubber, natural rubber supplies would be insufficient to meet world demands. Utilizing petrochemicals as basic raw materials, the synthetic rubber industry is predominately a southern industry.

B. Antibiotics

One of the spectacular developments of recent times has been the growth of the antibiotics industry. As early as 1900, Dr. Richmond of Fort Madison, Iowa, had discovered the curative properties of molds. Treating fever patients with capsules containing moldy bread and aspirin, he was able to effect many cures. His journal states that "Improvement is unbelievable. I shall give all my patients with fever and infections, mold. If I should tell the other doctors about this, they would think I'm crazy."

Patient research in England by Fleming led to the isolation of the active principle of mold, penicillin, just before the war. Its use during the war is credited with saving thousands of lives and greatly reducing convalescent time in infectious cases. In this country, the work of Waksman and his associates at Rutgers University led to the isolation of streptomycin from the soil.

Provided with this fundamental data, industrial research then developed methods for the mass production of these and other antibiotics. Their use has revolutionized medical practice in the treatment of many injuries, infections, and diseases. Retail sales of the antibiotics, unknown 15 years ago, amounted to more then $500 million last year.

C. Ammonia

The synthesis of ammonia ranks with the greatest discoveries of all time. Since the dawn of civilization, man had been living on the accumulated stores of nitrogen in the soil, and this capital was running out in the closing days of the last century. In 1887, Huxley, the great English economist, predicted that western civilization would disappear in fifty years as a result of the exhaustion of all available supplies of fixed nitrogen.

It is sometimes darkest just before the dawn, however, and this grim prediction did not come to pass. Research carried out in various schools and colleges had laid the basis for the fixation of atmospheric nitrogen by chemical means. In 1910, after ten years of research, Fritz Haber achieved the direct synthesis of anhydrous ammonia from hydrogen and nitrogen. At long last, man had discovered a way to renew his capital of this life-giving element indefinitely.

Continuing industrial research has made the nitrogen industry one of the giants of our time. At the outbreak of World War II, this country had a synthetic ammonia capacity of 400,000 tons. By 1944, this had been increased to 1,245,000. Present production is nearly 1,750,000 tons, and is being increased as rapidly as possible. The majority of this production is in the South. An additional 200,000 tons of annual yearly capacity is required to meet the food and fiber demands of our rapidly increasing population.

D. The McIntosh Development

The development of five new chemical plants near McIntosh along the Mobile river in southern Alabama illustrates the influence of chemical research

upon the development of an area. Some years ago, Dr. Stewart Lloyd of the University of Alabama discovered a salt dome near McIntosh while conducting a natural resources survey in that area. In 1952 Mathieson Chemical built a chlorine and caustic soda plant at McIntosh, using salt from the dome as the raw material. The plant has a capacity of 100 tons of chlorine a day. With an assured chlorine supply, Geigy built a DDT and BHC plant to supply these relatively new insecticides to the agricultural areas in the southeast. Calabama Chemical also is building a DDT plant at the same location.

Caustic from the Mathieson plant supplies the requirements of this basic chemical for the new Courtalds rayon plant at Le Moyne. Courtald's carbon bisulfide requirements come from a plant recently constructed by Stauffer at Le Moyne. Any excess caustic and chlorine from Mathieson's operation will find a ready market in the paper mills in southern Alabama. A systematic compilation of basic data by a university professor some years ago, coupled with advances made in chemical technology, has led directly to the industrialization of a large area and an assured income for many people.

E. The Semi-Synthetic Fibers

A recent development, employing the accumulated skills of many phases of science and the data resulting from generations of academic and industrial research, is the production of synthetic fibers. Until late in the last century only four fibers, namely, cotton, wool, silk, and linen, were available for the covering, warmth, and adornment of mankind. From the earliest times until the present, these fine fibers so generously provided by nature were sufficient to meet all of our needs.

But with the further development of the Machine Age, with its emphasis upon productivity and the large-scale manufacture of what had once been regarded as luxury items, an insatiable appetite for more and better textiles was created. The feminine wardrobe, which had been restricted to the commoner fibers for all

but the favored few, demanded increasing quantities of costly and exotic garments.

As living standards advanced, homes required more draperies, upholstery, table linen, sheets, and toweling. Automobiles, each requiring about 70 pounds of textile fibers, thronged the highways, and industrial and institutional needs multiplied.

As demands increased, certain limitations of natural fibers became apparent. The supply of silk and linen, the traditional luxury fibers, was limited and could not be increased substantially because of the high labor costs involved. Natural fibers are at the mercy of a number of unpredictable factors, such as weather, pests, and disease. The rising cost of farm labor became an increasingly important item. The base of our textile industry had to be broadened.

To satisfy these pent up demands came new types of fibers produced by the genius of man. Possessing many desirable properties, they have long since won recognition and a permanent place in our textile economy. Their development has resulted in a general improvement in all textiles as the natural fibers, determined not to be completely outdistanced by these upstarts from the laboratory, have redoubled their efforts to improve style, quality, and serviceability.

As a result of this competition between the various synthetic and natural fibers, Americans are the best-dressed people in the world. Today's wardrobes are larger and more varied, and clothing is more attractive, better fitting, and more serviceable. Yet since 1920, the portion of the consumer dollar spent for clothing has steadily declined. The miracle by which more and better garments have been made available at continually lower cost coincides with the period in which synthetic fibers have come into general use.

This is but a reflection of developments in other phases of our economy. The purchasing power of the individual has steadily increased with the development of new and better processes and products, leading to better quality or lower price. In the case of clothing, both price and quality have been improved, with a consequent

rise in our standard of living and our enjoyment of life. The steps by which such desirable results have been accomplished covers the history of modern scientific thought, although the inventive genius and the manufacturing skills of the present century were required for the actual production of synthetic fibers.

The brilliant British physicist Robert Hooke predicted the eventual development of artificial silk in 1664. Recognizing that the basic problem was the provision of a suitable "artificial glutinous composition - much resembling that out of which the silkworm wiredraws his clew," he stated that "if such a composition were found, it were certainly an easy matter to find very quick ways of drawing it out into small wires for use -- I need not mention the use of such an invention, nor the benefit that is likely to accrue to the finder, they being sufficiently obvious."

While we may question Hooke's designation of the development of suitable spinning techniques as an "easy matter," his procedure still serves as a blue print for the development of new fibers. Then, as now, the problem resolves itself into the basic steps of (1) providing a composition having the desired physical and chemical properties, and (2) shaping the composition into filaments of the required size and shape.

Despite this promising beginning, very little progress was made during the next two centuries, primarily because the science of chemistry had to advance to the point at which it could supply the "artificial glutinous composition" required by Hooke's process. In 1883, Weston produced experimental filaments from an ether-alcohol solution of nitrocellulose, and shortly thereafter Swan found that the product could be denitrified, thus regenerating the cellulose, by the action of ammonium sulfide. The stage was thus set for the production of an artificial fiber, although the basic raw material had been provided by nature's marvelous photosynthesis process instead of in the chemist's test tube.

Count Chardonnet then bent his keen mind to the task in the closing years of the century. A chance observation of a spaghetti machine extruding a plastic mass in the form of large filaments led him to the conclusion that a synthetic fiber could be produced if a solution of the proper composition was forced through minute orifices. After many false starts, the Weston-Swan process for the regeneration of cellulose was adopted, with promising results. This led to the construction of the first plant for the commercial production of rayon at Besancon, France, in 1891.

Later, a process was developed for the production of acetate, a semi-synthetic fiber formed by spinning a solution of cellulose acetate. Unlike rayon, which is a regenerated form of cellulose, acetate is a chemically modified form of cellulose.

Sold under the name of artificial silk, these semi-synthetic fibers were an instant success in a world hungry for more luxurious fabrics than the silkworm could produce. For silk, a scarce and costly item, had long been the only acceptable fashion textile. Although some of the rayon initially placed on the market was undeniably poor in quality, constant research improved its quality and appearance and developed from it the desirable rayon garments so familiar to us today.

The first plant for the production of rayon in this country was constructed at Marcus Hook in 1911, and is still being operated by the American Viscose Corporation. The first successful acetate plant at Cumberland, Maryland, which started operations in 1924. By 1930, rayon accounted for approximately 5% of the textile fibers sold in this country, and by 1938 rayon passed wool and was second only to cotton in terms of annual consumption.

The world rayon and acetate production was 3.4 billion pounds in 1952 (53% yarn, 47% staple), while the production in this country was 1,136 million pounds (72% filament yarn, 28% staple and tow). The U. S. production was 12% under the record 1951 production of 1,294 million pounds. The U. S. production capacity is 1.6 billion pounds at the present time, and is scheduled to increase to 1 3/4 billion pounds in 1954. The consumption of rayon and acetate in this

country in 1952 was 1,146 million pounds, 3% less than 1951 and 8% less than the record consumption of 1 1/4 billion pounds in 1950. The 1952 consumption was equivalent to 18% of our total fiber requirements.

Like the cotton textile industry, in which 88% of the cotton processed in the country is converted to cloth in southern mills, the production of rayon is predominately a southern industry. Approximately 70% of the nation's rayon production capacity is in the South, and contemplated new plant installations recently announced will increase this proportion even further. This is a logical location for the industry, as the basic raw material is cellulose in the form of cotton linters or wood pulp, both of which are available in almost unlimited quantities in the South. In addition, the mills in which rayon is converted to fabric are mainly located in the South. In 1952, 80% of all rayon and acetate produced by domestic manufacturers was processed in the South.

It is noteworthy that the advent of rayon did not result in any marked displacement of other fibers in the textile industry, but rather encouraged their use. Silk continued to be used in undiminished quantities until the outbreak of World War II effectively stopped all imports. A total of 29.2 million pounds of silk was consumed in this country in 1920, compared with 35.8 million pounds in 1940. The same situation prevailed with respect to cotton, the per capita consumption increasing from 17.7 pounds in 1930 to 26.3 pounds in 1950. In other words, increasing consumption of synthetic fibers had resulted in a corresponding increase in the consumption of natural fibers. The products complemented each other.

F. Synthetic Fibers

It is significant that the first of the man-made fibers to be produced commercially were derived from a natural polymer. Rayon is a semi-synthetic fiber in which the basic structure is synthesized by nature in the form of cellulose. Pure cellulose, in the form of cotton linters or refined wood fibers, is altered by physical or chemical processes, followed by dissolving and spinning.

Acetate is made in a similar manner, with the exception that the cellulose acetate fibers obtained from the spinning process are not reconverted to cellulose prior to use.

In the meantime, great strides had been made in chemistry and in the understanding of the complex structure of large molecules, mainly as a result of theoretical investigations pursued for years in schools throughout the world. This knowledge was at last sufficient to enable man to attempt to duplicate nature's work in constructing large molecules from simple basic materials.

In 1927, the DuPont Company inaugurated a fundamental research program which was to result in the first true synthetic fiber, one composed of molecules entirely formed by the hands of man according to a prearranged pattern, starting with chemical raw materials. A whole new industry was to be born.

Nylon, the product of this development, was placed on the market in 1939, and soon began to challenge silk in the field of ladies' hosiery. In this use, it was found to outlast silk several times over, and the word itself became synonymous with ladies hose. Quickly displacing silk in the manufacture of fine and luxurious garments, it is regarded by many textile experts as the outstanding fiber among all natural and synthetic fibers. Hooke's prophecy had been fulfilled.

Probably no major product has ever timed its entry into the industrial field so well. Possessing many of the properties of silk, it was immediately pressed into military use as soon as the supplies of this natural fiber were cut off as a result of our war with Japan. Without nylon for the fabrication of parachutes, glider tow ropes, and a thousand and one other military items, our war effort would have been severely handicapped.

At the end of the war, the pent up demand for nylon knew no bounds. War surplus parachutes were cut up to make dresses and other articles of apparel, and nylon waste of all kinds was eagerly snatched up.

DuPont has made every effort to keep production and demand in some semblance of balance, and is now engaged in the eighth major expansion of nylon production facilities since the war. Even this has been insufficient to supply the demand, and whole fields of application have been neglected due to the impossibility of diverting any of the product from established outlets.

The raw materials (intermediates) required by DuPont's nylon operations come from plants located at Orange, Texas; Victoria, Texas; and Niagara Falls. Spinning plants are located at Seaford, Delaware; Martinsville, Virginia; and Chattanooga, Tennessee.

In 1951, the Chemstrand Corporation was licensed to manufacture nylon and started to construct at Pensacola, Florida, the first completely integrated plant ever built for the production of nylon. More recently, Allied Chemical announced its intention of building a plant for the production of Nylon 6, a nylon—type fiber, at Bermuda Hundred, Virginia, and American Enka plans to build a small plant for the manufacture of Nylon 6 at Enka, North Carolina.

Encouraged by the warm reception accorded nylon, the textile industry has demanded additional new fibers having a whole spectrum of unusual properties to enable new fabrics and styles to be developed for the discriminating retail trade. As not all of the properties required were available in natural fibers, or in the synthetic fibers already on the market, large research and development programs were initiated by chemical and fiber companies to meet these demands.

The fruits of these endeavors have been making the headlines for the past two years, ushering in a new era in an industry older than the pyramids. With the broad range of properties available in the new synthetics, and the almost infinite varieties that can be created by the skillful blending of these new fibers with natural fibers and the established synthetic fibers, the textile industry is looking forward confidently to the development of a host of new apparel and other consumer items in which new styling, comfort, and durability standards will

be attained. For the chief consumer appeal of these new synthetics is that they will bring the quality associated with the luxury fibers in the past within the reach of everyone.

So intense has been the public's interest in these new fibers that many, such as Orlon, Dacron, Acrilan, and dynel, became household words before they appeared on the market in any substantial quantities. And the end is not in sight as other chemical and textile companies get on the bandwagon. Cyanamid (X-51), Eastman (M-24), Industrial Rayon, Goodrich, and Allied Chemical are known to have acrylonitrile fibers in various stages of development, and some may be expected to be available in commercial quantities in the near future.

Acrilan, Orlon, and dynel are spun from acrylonitrile polymers and copolymers and are commonly referred to as acrylic fibers. Acrylonitrile is manufactured from ethylene oxide by Cyanamid at Warners, New Jersey, and by Carbide and Carbon at South Charleston, West Virginia. Monsanto obtains acrylonitrile from acetylene at Texas City, Texas, and Cyanamid is building a second acrylonitrile plant near New Orleans.

Dacron is a polyester fiber, presumably derived from the reaction of terephthalic acid with ethylene glycol. A similar fiber is being produced on a small scale in England and sold under the name of Terylene.

Acrilan is produced in staple form in the new Chemstrand plant at Decatur, Alabama.

The DuPont plant for the production of Orlon in both continuous filament and staple forms is located at Camden, South Carolina.

Carbide and Carbon has a dynel plant at Charleston, West Virginia, and has recently announced plans for the construction of a much larger plant at Spray, North Carolina.

DuPont is just completing a large plant for the production of Dacron at Kinston, North Carolina, and has discontinued its pilot plant production of Dacron at

Seaford, Delaware. The Kinston plant will produce both continuous filament and staple Dacron.

Although produced by different companies and by different processes, these new synthetic fibers share certain properties in common. They have excellent warmth and warm-to-the-touch factors, and hence should find widespread application in the apparel field, such as in men's and women's suitings and outerwear, in blankets, and in pile fabrics. They are not attacked by moths, mold, mildew, or insects, which is of great consumer interest in view of the one hundred million dollar annual loss resulting from moth damage alone in this country. These fibers do not absorb moisture to any appreciable extent and hence garments fabricated from them can be given semi-permanent heat-set creases. This factor also contributes to their wrinkle resisting properties. They have low specific gravities, which results in bulk without weight for excellent covering power.

With these desirable properties as a base, each fiber then develops its own individuality through the possession of certain unique properties, such as ease of dyeing and processability, unusual styling characteristics, desirable hand, and the like. Each has important contributions to make to the style-conscious and quality-conscious textile market.

The following list of outstanding properties was recently compiled by the Robert Shook Associates in a survey of the synthetic fiber field.

Fiber	Outstanding Property
Nylon	Abrasion resistance.
Orlon	High bulk.
Dacron	Great resilience.
Acrilan	Bulking power, dyeing, and resistance to pilling.
dynel	Resistance to burning.

As the majority of the new synthetic fibers are being used in the form of blends, a brief summary of the desirable properties which may be imparted to the finished fabric by the use of certain of these fibers, such as Acrilan, or one of the other acrylic fibers, is of interest. A recent survey has indicated that the following plus values can be obtained by the use of one or more of the synthetic fibers in blends containing natural fibers or the semi-synthetic fibers.

1. Improved wear resistance
2. Day-long freshness
3. Life-long appearance
4. Improved launderability
5. Quick drying
6. Warmth without weight.

The use of synthetic fibers is growing at a rapid rate, the only limitation at the present time being the supply of raw materials and insufficient production capacity. The 1952 consumption was 250 million pounds, equivalent to 4% of our total fiber consumption.

The President's Materials Policy Committee recently published the following estimate of synthetic fiber production in this country for 1960 and 1975.

	Consumption in Millions of Pounds	
Fiber	1960	1975
Nylon	300	800
Acrylics	325	1,200
Dacron	150	1,000
Miscellaneous	200	1,000
	975	4,000

Although most textile technologists will regard the 1975 estimates as excessive, the production of synthetic fibers is expected to increase several-fold between now and 1975.

The present selling prices of synthetic fibers in staple form (average deniers and staple lengths) is given in the following table.

Staple Fiber	Selling Price - Dollars per Pound
Orlon	1.90
Dacron	1.90
Acrilan	1.85
Nylon	1.70
dynel	1.28

The 1952 consumption of all fibers in this country was as follows:

Fiber	Millions of Pounds	Weight % Basis	Dollar Value Basis	Variation from 1951 Weight Basis
Cotton	4,479	71	49	-9%
Rayon (and Acetate)	1,146	18	21	+3
Wool	468	7	20	-6
Synthetic	260	4	10	-17
Silk	7	-	-	-
	6,360	100	100	

An outstanding factor in the growing use of synthetic fibers is price stability. Wool, which was priced at $1.65 per pound in 1948, jumped to $4.00 shortly after the outbreak of the Korean war, dropped to $3.00 by the end of 1950, and is now selling for $1.70. Rayon during the same period, fluctuated in price between the narrow limits of 36 to 40¢ per pound, and nylon was even more stable in price. Based on readily available chemical raw materials, the new synthetic fibers, such as the acrylic fibers, undoubtedly will be quite stable in price and will have a stabilizing influence on the price of other fibers. The stabilizing influence of synthetic rubber upon the price of natural rubber is an outstanding example of what can be accomplished in this direction.

Another advantage furthering the development of the new synthetic fibers is uniformity. Made under rigidly controlled operating conditions from raw materials of unvarying quality, they can be produced to meet the precise specifications required by the fabric and apparel industries. As further experience is gained in their production, it is expected that even more rigid specifications can be met.

Synthetic fibers are derived almost entirely from natural gas, petroleum, limestone, salt, and other readily available raw materials. Man is thus turning increasingly from agricultural products to minerals for his clothing and other fiber and fabric needs.

Using the acrylics, the fastest growing fiber family, as an example, acrylonitrile is first manufactured from natural gas by a series of four reactions. The light straw-colored liquid is then shipped to the synthetic fiber plant, where it is polymerized to form a solid material composed of long, thread-like molecules. The polymer then is dissolved in a suitable solvent, pumped through minute orifices, dried, crimped, cut and baled.

A pound of Acrilan can be obtained from 125 cubic feet of natural gas (methane) and 500 cubic feet of air. Assuming a straight-through process, approximately 8 hours is required to convert the natural gas to Acrilan staple.

Three general types of spinning are employed in the production of synthetic fibers, namely, melt spinning, wet spinning, and dry spinning. In melt spinning, which is used in the production of nylon, the polymer is melted, forced through minute openings in a spinerette, and solidified in a chimney to form filaments by a blast of cold air or gas. The wet and dry spinning processes start out with a solution of the polymer in a suitable solvent, but in the former the solution is forced through a spinerette into a coagulating bath, while in the latter the fibers discharge from the spinnerette into a chimney where a blast of hot air or gas serves to remove the solvent. Rayon is produced by the wet spinning process and acetate by the dry spinning process.

Synthetic fibers are produced in the form of monofilaments, continuous multifilaments (yarn and tow), and staple. Staple is commonly produced in 1 1/2 to 5 denier types, and with staple lengths from 1 1/2 to 5 inches.

The capital investment required per annual pound of staple fiber production ranges from $1.00 to $1.50, while the corresponding investment for continuous filament production ranges from $2.00 to $2.50. It has been estimated that $40 million is required to place a new fiber on the market on a plant-scale operation basis, and $150 million is required to construct and operate a fiber plant for the production of 50 million pounds of fiber per year, including the cost of the auxiliary plants for producing the chemical raw materials.

The synthetic fiber industry is almost exclusively a southern industry. With one or two exceptions, all of the synthetic fiber plants now in operation, or in the course of construction, are located in the South, and all of the recently announced new plants are to be built in the same area. The South, in fact, is the only logical location for the industry. The basic raw materials for the production of synthetic fibers are largely obtained from the petrochemical plants situated on the Texas Gulf coast, and the synthetic fibers so produced are converted to finished textiles in the spinning, weaving, and finishing mills located in the southeast.

The southern chemical industry rests on a firm and secure basis from a raw material standpoint. The South has a wide variety of minerals and many are available in very substantial amounts. The total value of all minerals produced in the South in 1950 was 4 1/2 billion dollars, or 44% of the nation's total. More than half was produced in Texas, and petroleum accounted for 78% (3 1/2 billion dollars) of the total. Coal and petroleum together amounted to 90% (4 billion dollars) of the overall mineral production.

The total southern production of petroleum, its most important mineral resource, was 1.7 billion barrels, equivalent to 66% of the nation's total in 1951.

Present proven reserves of oil in the United States amount to approximately 32 billion barrels, of which the South has about 70%.

On the basis of the present rate of consumption, which has been rising steadily and rapidly, present proven reserves of oil are sufficient for 13 years. To offset this, new reserves are constantly being discovered and for the past twenty years proven reserves have increased steadily despite rapidly rising consumption.

The production of natural gas in the South now amounts to 6 trillion cubic feet, 75% of the total production in the country. In dollar value, it is the South's second most important mineral. Known reserves will last for 25 years at present rates of consumption, and approximately 80% of the reserves are located in the South.

By 1950, the South had 25% of the chemical manufacturing plants in the country, 32.5% of all persons engaged in the chemical industry, 31.6% of chemical income, payrolls, and profits, and 32% of the chemical sales of the country. Substantially every large chemical company, including such giants as DuPont, Carbide and Carbon, Allied, Monsanto, and Dow, now has one or more plants in the South. As a clear indication of the trend, DuPont, the world's largest chemical company, has nearly half of its total investments and inventories in the South.

Parelleling this rapid development in chemical manufacturing facilities, which provide the raw materials for the production of synthetic fibers, was the growth of the textile industry in the South. Originally a New England industry, more than 80% of the cotton spindles and 70% of the looms are now located in southern states. Southern mills process 88% of all of the cotton used in this country, employing more than 500,000 workers in 1000 textile mills. Wages and profits amount to more than $3 billion per year, and the sales volume is over $7 billion per year. The textile industry is the South's most important industry.

North Carolina, now the heart of the industry, has 25 per cent of the nation's 23 1/2 million spindles, followed by South Carolina with 24%, and Georgia with 13%. Plants in the woolen and worsted industry are moving to the same areas in ever increasing numbers.

When present synthetic fiber plants now under construction have been completed, from 20,000 to 30,000 new looms will be required to convert the fiber into fabric. The South will be in a very good position to handle this increased volume of business. Over $500 million was expended in the South in 1952 to expand textile mill capacity to process an additional 400 million pounds of fiber per year.

The textile producing and processing industries now consume approximately 25% of all of the industrial chemicals produced in this country, and this proportion undoubtedly will increase as more of our fiber requirements are obtained by the use of chemical raw materials.

The synthetic and semi-synthetic fiber industries already have grown to large proportions. Total sales are in excess of one billion dollars, and plant investments have almost reached the same amount. Raw material purchases amount to 500 million dollars per year, and the yearly payroll is in excess of 250 million dollars. It has been freely predicted that the manufacture of synthetic fibers will become one of the South's most important industries.

The Need for Synthetic Fibers

Synthetic fibers are required in ever increasing quantities to clothe the people in the world due to increasing competition between food and fiber crops for available land. The past three centuries have witnessed a phenomenal growth in world population. Estimated at 400 million in 1640, it is now approximately 2 1/4 billion and is increasing at the rate of 1% per year. This has been accompanied by an equally rapid decline in the amount of land adapted to food and fiber production due to erosion, improper use, and overcultivation. The available

arable land on the globe is now estimated at not more than 2 1/2 billion acres, or slightly more than one acre per person. As a result, over half of the people in the world go to bed hungry each night.

The total world fiber consumption during the past few years has tended to outrun production. In fact, the supply of natural fibers would have been inadequate to meet our textile needs if substantial quantities of semi-synthetic and synthetic fibers had not been available.

The world production of the four principal textile fibers - cotton, rayon, wool, and silk - was 18 1/4 billion pounds in 1950, the last year of free economy before the Korean War. This is identical with the world production of the same fibers in 1936, despite an increase in the production of synthetic fibers from 1/3 to 3 1/2 billion pounds during the same period. As world population has increased substantially during this period, the overall fiber supply would have been inadequate to take care of the needs of the people if the production of synthetic fibers had not increased at a rapid rate during the same period.

In the United States, natural fibers seem to be approaching the upper limit of productivity due to increasing competition with food crops. Cotton production, in particular, seems to be leveling off at 15 million bales per year. Despite every inducement by the U. S. Department of Agriculture to produce 17 million bales of cotton in 1951, and 16 million bales in 1952, only 15 million bales were ginned each year. This could develop into a serious situation if synthetic fibers were not available as population growth will increase our total fiber requirements in the apparel and household fields alone by the equivalent of a million bales every 4 1/2 years.

The wool industry is faced with an even more serious problem. Since the end of World War II, world wool consumption has exceeded wool production by 1 1/2 billion pounds.

This situation is brought into sharp focus by trends in the United States.

In 1870, there were as many sheep as there were persons in this country - 40 million of each. By 1950, the human population had increased to over 150 million, while the sheep population had declined to 28 million. In other words, the ratio between sheep and people in the United States had declined from 1:1 in 1870 to 1:5 in 1950.

The production of domestic wool has been declining for the last decade and is now 40% less than it was in 1942. As a result, the major portion of our wool requirements must be imported. In 1952, we consumed 468 million pounds of wool, but produced only 120 million pounds. This means that three out of every four pounds of wool consumed in this country last year were produced in other countries.

Additional quantities of fibers must be provided to meet the needs of the growing population in this country, which is increasing at the rate of 7,400 per day, or 2 3/4 million per year. This increased fiber production must come from the synthetic fiber industry, as the quantity of land available for natural fiber production is steadily declining.

It requires approximately 2 1/2 acres of land per person to maintain our present standard of living. By 1960, it is estimated that there will be less than 2 1/2 acres of arable land for each person in this country, due to increasing population and declining acreage resulting from improper land use and erosion. The pressure for foodstuff production then will even further reduce the acreage available for growing fibers.

The United States will need 120 million more acres of arable land by 1975. As only 30 million acres can be obtained by draining, irrigation, and clearing, the rest must be obtained by increasing yields and by increasing conversion of land from fiber production to food production.

The 1950 consumption of fibers in this country was 6.4 billion pounds, equivalent to a per capita consumption of 34 pounds (22.1 pounds of cotton, 7 pounds of semi-syntheitc, 3.2 pounds of wool, and 1.5 pounds of synthetic). At this rate of consumption, 100 million pounds of additional fibers will be

required each year to meet the textile requirements of our growing population. Increasing amounts undoubtedly also will be required to take care of increased per capita consumption of fibers.

The Outlook for Synthetic Fibers

Having pointed out the need for increasing supplies of fibers for use in textile and other applications, one is tempted to ask why more companies are not investigating the possibilities in this field. The answer is not hard to find. Large sums of money are required for research and development purposes, initial plant investment costs are unusually high, and the product must be sold in a very volatile and unpredictable market.

The synthesis of a new fiber is a relatively easy task, but to select the proper one for commercial exploitation is extremely difficult. The route from the laboratory to the large scale production of fabrics and finished garments is a very hazardous one, and the development of a new synthetic fiber involves many risks. The early history of the rayon and acetate industry is littered with the wreakage of companies which attempted to engage in the manufacture of these new fibers.

The research and development costs required for a new fiber can easily amount to $10 million or more. This is not an excessive estimate as DuPont has stated that some $27 million has been expended in nylon research alone. Since it is very difficult to explore the market fully on anything less then full scale production, the initial plant may cost from $30 to $50 million and require another $20 million as working capital. The total investment in the project can easily amount to $70 million. As a matter of fact, it has been said that the first pair of nylon stockings represented an investment of some $70 million. If intermediate manufacture is required, the total may be increased by 50 to 100%. The modern synthetic fiber industry is a field for giants, and can be entered only with great risk and courage.

The marketing of synthetic fibers is a hazardous undertaking, due to the unpredictable nature of the textile industry. Pilot plant operations usually are not extensive enough to give a true picture of the processing characteristics of the fiber, which is quite important from the standpoint of economical mill operations, and sales development on this scale can be dangerously misleading. One is then forced to choose between inadequate market sampling at a reasonable cost, or a complete market evaluation on a large scale production basis. In the last analysis, extensive, large-scale testing of the market must be conducted.

In view of these considerations, only those companies with a long record of successful operation, adequate financial backing, and experience in the textile field, or in related fields, may be expected to engage in the large scale production of synthetic fibers. Fortunately a sufficient number of such companies are engaged in synthetic fiber production at the present time to insure an adequate supply of fiber to meet all of the needs of our expanding economy.

The Future of Industrial Chemical Research

In the past, the explorer, the empire builder, and the railroad magnate have, in turn, striven to widen man's horizon and provide a better way of life. Chemistry is the last great frontier.

It is not difficult to predict that academic research and industrial chemical research will continue their fruitful partnership to provide for the ever increasing needs of our advancing civilization. That they will make the luxuries of today the commonplace items required by the average person of tomorrow is to be expected on the basis of their performance in past years.

We may confidently expect that increasing emphasis will be placed on the improvement of agriculture through the use of chemical fertilizers, soil conditioning agents, herbicides, insecticides, and similar materials in order to increase the output of food and fiber to meet the needs of our growing population. The development of more and better synthetic fibers, plastics, and rubbers will be required

in order to provide more acreage for the production of foodstuffs.

The development of new and improved processes for the isolation of metals from low grade ores to replace our vanishing supplies of high grade ores will be accelerated. The ocean will be increasingly mined for metals and chemicals.

The production of chemicals from petroleum and natural gas will continue at an accelerated pace, and processes for the production of liquid fuels from shale, coal, and other carbonaceous sources will develop into large-scale enterprises.

With the increasing application of scientific principles to solve our industrial problems, we may look foreward to the future with confidence, secure in the knowledge that a continuing improvement in our way of life will result.

The Role of Applied Mathematics in Scientific and Engineering Research

Friedrich O. Ringleb

The denotation "applied mathematics" seems to indicate that there exist special fields within the total area of mathematics which are connected only, or at least mainly, with applications. There have been combined, indeed, under this denotation several fields in academic courses and textbooks, such as numerical and graphical methods, nomography, vector- and tensor-analysis, descriptive geometry, theory of probability, statistics and others. However, all of these fields belong in fact to the field of pure mathematics. There is no basic difference, for instance, whether an algebraic equation is solved in general symbols or numerically in a special case. The procedure of solution is in both cases a purely mathematical one and the numerical equation represents no specific application as such. Vector analysis is both a method of analytic geometry and a symbolical method belonging to the field of pure mathematics. On the other hand, there is no field of mathematics which has been applied more frequently to problems of science and engineering than differential and integral calculus. It is odd enough that nobody has denoted this field as "applied mathematics."

In fact, there exists no field which can be called "applied mathematics." <u>There exists on the one side only the purely spiritual world of mathematics, an ideal and completely unreal creation of the human spirit, and on the other side the real, material world of natural phenomena. However, there exists also an analogy between these two worlds.</u>

This means that to any natural phenomenon can be coordinated a mathematical process which runs parallel to the natural process and which has the character of an isomorphism in the language of the abstract algebrist. It is not intended nor possible to discuss this conception here in general terms. The meaning of such coordination will be understood more easily by considering some examples.

Application of mathematics to a problem of science or engineering is equivalent to the establishment and discussion of a mathematical analogy. It is very interesting

that we feel we are not able to describe correctly and to understand a natural phenomenon without such an analogy. Only if we restrict ourselves to a qualitative description of the nature of the phenomenon may we be able to avoid it. As soon as we enter the field of exact science, however, which means quantitative description of the nature of the phenomenon, the mathematical analogy appears automatically by itself. A set of measurements, for instance, means the establishment of a set of numbers and, therewith, a mathematical analogy. If the engineer plots a measurement on graph paper and draws a curve through the measured points, he establishes a mathematical analogy. The curve is the geometrical analog to the measured natural process.

The mathematical analogy enters the field of exact science already with the formulation of the basic conceptions, definitions and laws. The motion of a point x along a straight line can be defined only by a function $x = f(t)$. The conception of the velocity v can be defined only by using the mathematical conception of the derivative

$$v = \frac{dx}{dt} .$$

The acceleration "a" of the point x can be defined only by the mathematical analogy

$$a = \frac{d^2x}{dt^2} .$$

Newton's law that force equals mass times acceleration is, therefore, not conceivable without mathematical analogy. This law could not be understood and therefore could not be found without a mathematical analogy.

Let us consider now some examples of mathematical analogies which we will choose out of the field of mechanics. A mass point m, for instance, is supposed to move within a straight line (see Fig. 1) under the action of a force F which varies in a given way with the time t, with the position x of the mass point and with its velocity $\frac{dx}{dt}$. So the force F is a given function of t, x and $\frac{dx}{dt}$, and the equation of motion

is, according to Newton's law,

$$m\frac{d^2x}{dt^2} = \mathcal{F}\left(t, x, \frac{dx}{dt}\right) \tag{1}$$

This is an ordinary differential equation of second order for the unknown function

$$x = f(t) \qquad (2)$$

which describes the motion of the mass m under the action of such force. The differential equation is of a quite general type. So we can state: the mechanics of a mass point m moving in a straight line under the action of a force which depends on the time, the position of the mass and its velocity, is an analog to the theory of an ordinary differential equation of second order, and inversely. Every mechanical problem of this type corresponds now to a mathematical problem concerning an ordinary differential equation of second order, and every theorem valid for such a differential equation can be interpreted as a mechanical phenomenon of a mass point moving in a straight line.

The function $F = F\left(t, x, \frac{dx}{dt}\right)$ is supposed to be a real function of the variables, of course. The differential equation, however, must not have a real solution $x = f(t)$. If the mathematical investigation shows that such a solution does not exist, it is proved that a mechanical system defined by the function F is impossible in reality.

If F is any given function it will be impossible in general to solve the differential equation (1) in a closed form. However, there are types of function F for which the equation can be solved by elementary functions and simple integrations. For instance, the linear equation

$$m\frac{d^2x}{dt^2} + A\frac{dx}{dt} + Bx = g(t),$$

the equation of a forced vibration, can be solved in a closed form if A and B are constants.

In the general case a numerical solution can be performed always by numerical or graphical methods using, eventually, computing machines. However, every such solution is valid only for a special set of the numerical coefficients of the equation; and if there is a larger number of coefficients involved, the variation of all these coefficients necessary to obtain a complete insight into the possible solutions

of the problem will cause a tremendous computational labor, even if modern computors are used. It is obvious and generally acknowledged that such numerical methods can never replace the mathematical theory. If now the correct mathematical analogy is too complicated for a theoretical discussion with symbolical coefficients, this analogy has to be replaced by a simpler one omitting nonessential features in the problem. In this way an appropriate analogy will be obtained. The success of such a procedure depends largely on the skill of the so-called applied mathematician who has to be ingenious in finding those unimportant changes which result in a mathematically treatable analogy.

In the case of problems belonging to the example described, and to many other cases, a linearization of the problem will be tried at first. However, this is not always possible without too large a deviation from the truth. A considerable number of important problems of practical mechanics yield, for instance, equations of the type

$$m\frac{d^2x}{dt} + f\left(\frac{dx}{dt}\right) + g(x) = h(t)$$

without possibility of change into linear equations. This field of non-linear mechanics is one of the most modern areas of research. The mathematical theory has to furnish the solutions of the problems in this field and has to guide the experimental work.

Let us consider next an impact problem. Such problems too are in the center of interest at the present time. The example to be discussed here, however, has been treated already (in the last century) by d'Alembert. H is the axial impact on an infinitely long elastic bar. Impact means a discontinuity in the velocity. The end surface A

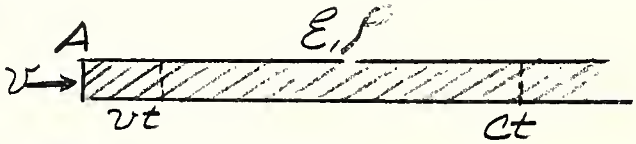

FIG. 2

of the bar, originally in rest, suddenly moves with the constant velocity v (see Fig. 2). So the velocity of this surface jumps from the value zero to the value v.

The surface A moves during the time t about the amount vt compressing the bar. To be determined is the stress produced by this compression. We assume that Hooke's law, according to which the stress is proportional to the contraction, is valid. We denote by E the elasticity modulus and by ρ the mass density of the material of the bar. The compression front runs along the bar with the velocity c of sound of the material which is known to be

$$c = \sqrt{\frac{E}{\rho}} \quad . \tag{3}$$

So the compression front has at the time t the distance ct from the original position of the surface A. Beyond ct every particle of the bar is in rest. Only the length ct is influenced by the impact during the time t. The contraction of this part ct of the bar is equal to vt. The stress σ in the bar is, therefore, according to Hooke's law,

$$\sigma = E \cdot vt \tag{4}$$

or because of (3)

$$\sigma = v\sqrt{E\rho} \quad . \tag{5}$$

This is d'Alembert's formula representing the mathematical analogy of the impact described above. It shows that the impact stress is proportional to the velocity of the impact. From a modern point of view, formula (4) or

$$\frac{\sigma}{E} = \frac{v}{c} \tag{6}$$

is preferable. Instead of the constants E and ρ characterizing the material of the bar, formula (6) contains the constants E, the elasticity modulus, and c , the velocity of sound, as constants of the material. In this way, the mathematical analogy has been reduced to the simplest form which is possible at all - namely to the equation x = y of two variables $x = \frac{\sigma}{E}$ and $y = \frac{v}{c}$ which are dimensionless. The first of these numbers is the ratio of a variable and a constant stress, the second the ratio of a variable and a constant velocity. The last ratio is called Cauchy-number and corresponds to the same ratio in gasdynamics, called Mach-number.

This example is intended to show that greatest simplicity in the establishment of a mathematical analogy will be reached by the use of dimensionless variables and coefficients. This is the purest form of mathematical representation of a natural phenomenon. Such an analogy does not contain any natural units. The natural process is completely arithmetized.

The study of such dimensionless representations has been developed in recent times to a wide and extremely important field of modern research, called dimensional analysis.

There is hardly any other more beautiful and perfect example for a mathematical analogy than the following which we are going to discuss now. It is the mathematical representation of two-dimensional, steady, irrotational flow of an incompressible, frictionless medium.

That the flow is supposed to be steady, independent of the time, two-dimensional and irrotational means only that we consider a special type of flow. The suppositions however, that the flow is frictionless and the flow medium incompressible are neglected parameters in order that a simpler mathematical analogy may be obtained. They mean an idealization of the flow. The friction is now indeed negligibly small if the velocity gradients perpendicular to the flow direction are not too large, and the supposition of incompressibility is satisfied with good approximation for liquids and also in the case of gases, if in this case the velocity of the flow is small compared with the velocity of sound. If these conditions are not satisfied, however, we have to expect that the mathematical analogy will not be in agreement with the observation.

If the position of the flowing particles is represented by the coordinates x, y in a rectangular coordinate system, and if the velocity components u, v of every particle are determined as functions of x and y, the mathematical analogy will be established. The analysis of the problem shows that two functions, $u = u(x,y)$ and

$v = v(x, y)$, represent the velocity components of such a flow if, and only if, the conditions

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \quad \frac{\partial u}{\partial y} - \frac{\partial v}{\partial x} = 0 \tag{7}$$

are satisfied. These two partial differential equations can be solved. The solution can be represented in the most simple way if instead of real variables, complex variables are used. The result is this: we denote by the complex variable

$$z = x + iy \tag{8}$$

and by x the complex variable

$$\chi = \phi + i\psi \tag{9}$$

If now

$$\chi = f(z) \tag{10}$$

in any analytical function of z the velocity components u, v of a flow are obtained by

$$u - iv = \frac{d\chi}{dz} = f'(z). \tag{11}$$

So the real and the negative imaginary part of the derivative of the function f(z) represent the velocity components of a flow. Inversely, every flow of the described type can be obtained in this way. The imaginary part of the function f(2) itself determines the streamlines of the flow, the lines in which the particles are moving. For every streamline is

$$\psi = \psi(x, y) = \text{constant.} \tag{12}$$

Let us consider some special cases. If, for instance,

$$\chi = f(z) = U_0 z$$

where U_0 is a real constant, we obtain

$$u - iv = \frac{d\chi}{dz} = U_0$$

or

$$u = U_0, \quad v = 0$$

which is a flow parallel to the x-axis with the velocity U_0.

We have $$\chi = \phi + i\psi = U_0(x + iy).$$

Thus
$$\phi = U_0 x \quad , \quad \psi = U_0 y .$$

The streamlines, ψ = constant, are the lines

$$y = \text{constant}.$$

The flow can move in both directions on these lines. It is convenient, however, to define as direction of the flow the direction of increasing values of ϕ. So we get for a positive V_0 the flow in the direction of the positive x - axis.

Let us consider further the function
$$\chi = f(z) = z^2 .$$

Here we get
$$\chi = \phi + i\psi = (x + iy)^2 = x^2 - y^2 + 2ixy .$$

The streamlines are (see Fig. 3)
$$\psi = 2xy = \text{CONSTANT}.$$

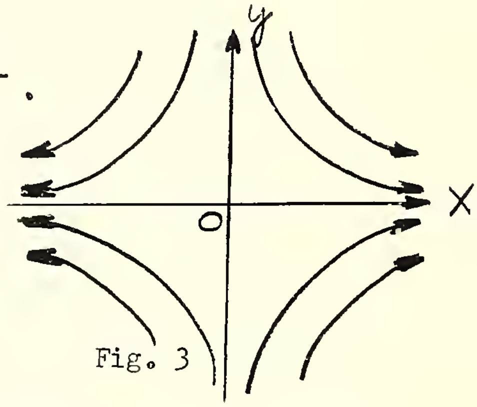

Fig. 3

The velocity components are given by
$$\frac{d\chi}{dz} = u - iv = 2z = 2(x + iy) .$$

Thus
$$u = 2x \qquad v = -2y,$$

The point x = y = 0 yields u = v = 0. It is a stagnation point.

In the general case, a point z_0 is called a regular point of the function $\chi = f(z)$ if $f(z)$ can be expanded into a series of the form

$$f(z) = C_0 + C_1(z - z_0) + C_2(z - z_0)^2 + \cdots \tag{13}$$

If now $C_1 \neq 0$, the flow behaves near z_0 like a parallel flow. If $C_1 = 0$, the flow has a stagnation point at $z = z_0$ because then

$$u - iv = f'(z) = 2C_2(z - z_0) + 3C_3(z - z_0)^2 + \cdots$$
$$= 0$$

for $z = z_0$. If an expansion of the form (13) does not exist around z_0, this point is called a singular point of the function.

The singularities of a function require the utmost consideration. Every function is characterized by its singularities. A function without singularities, for instance, is a constant; a function with one singularity of the type $\frac{1}{z-z_0}$ is a linear function. To the singularities of the function correspond the singularities of the flow; they define the singularities of the flow. So a flow investigation will have to start with an investigation of the flow singularities. Besides, this is true not only in this case. Always, where a natural phenomenon is represented by functions, the singularities of these functions and the corresponding singularities of the natural phenomenon require the primary interest and offer, principally, the key for understanding and solving the problem.

Let us consider here, as an example, the function

$$X = f(z) = \frac{\Gamma i}{2\pi} \ln z$$

which has a singularity at $z = 0$ (and another one in the infinity). Γ is supposed to be a real constant. We introduce polar coordinates for the point x,y, setting

$$x = r\cos\theta, \quad y = r\sin\theta$$

so that

$$z = x + iy = re^{i\theta}.$$

We get then

$$X = \frac{\Gamma i}{2\pi} \ln(re^{i\theta}) = \frac{\Gamma i}{2\pi}(\ln r + i\theta)$$
$$= \phi + i\psi.$$

Thus

$$\phi = -\frac{\Gamma}{2\pi}\theta, \quad \psi = \frac{\Gamma}{2\pi}\ln r.$$

The streamlines are the concentric circles r = constant (see Fig. 4). The function represents a vortex.

$\Gamma > 0$

Fig. 4

The vortex is one of the most important flow singularities. This becomes obvious if we consider the behavior of a vortex which is superposed on any other regular flow. This means that f(z) has the form

$$X = f(z) = g(z) + \frac{\Gamma i}{2\pi} \ln z \quad (14)$$

where g(z) is any function which is regular at the point $z = 0$, having there the expansion

$$g(z) = C_0 + C_1 z + C_2 z^2 + \dots \quad (15)$$

We can show, using a formula by Blasius, that in general a force is acting now on the vortex. The components X and Y of this force follow from Blasius' formula which results in

$$Y + iX = \rho \Gamma C_1 . \quad (16)$$

If, for instance, g(z) represents a parallel flow

$$g(z) = U_0 z \quad (17)$$

we have

$$C_1 = U_0$$

and, therefore,

$$X = 0, Y = \rho \Gamma U_0 . \quad (18)$$

This shows that the vortex gets lift perpendicular to the direction of the parallel flow. This special result is known as the Kutta-Joukowski theorem and is the basis of classical aerodynamics. It is the vortex around the wing section of an airplane which produces the lift in the parallel flow. There was no progress in flight until this result had been derived mathematically.

But this is not the only way to use a vortex practically. We are trying today to produce desired flow effects by producing free-stream vortices and by keeping them in a stable position, for instance near a wing surface. It can be observed in nature that such vortices exist. Behind a dam reaching from the shore into a river such a vortex normally forms and can be seen turning if dry leaves cover the surface of the water. Also, behind snow cornices on high mountains such fixed vortices can

be observed. It is relatively seldom, however, that a vortex has a fixed position. There arises the interesting but difficult problem of finding stability conditions for a vortex or vortices. A necessary condition follows immediately from formula (16). If a free-stream vortex is in a stable position, there can be no force acting on it. Thus X and Y must be zero. Then C_1 has to be zero, which means that the basic flow on which the vortex is superposed, which is the flow represented by

$$\chi = g(z)$$

has a stagnation point at the place where the stable vortex is situated.

The vortex is, of course, not the only flow singularity. There are sources and sinks and other singularities of theoretical and practical importance. Only a short time ago aerodynamic research began to consider the possibilities of flow control by application of artificially produced flow singularities. We are here at the beginning of a quite new and large development, and here even more than before the mathematical analogy will not only furnish the explanation of observed effects but also guide the investigation and experimental work.

The same mathematical analogy can belong to different natural phenomena. The last example is such an analogy. It belongs in exact correspondence to a certain group of electromagnetic phenomena. In this way, the mathematical analogy can prove the analogy of natural phenomena, though they may appear to be very different. The mathematical analogy can be used also to solve mathematical problems, for instance certain types of differential equations, by experiment. The electronic analog computors are an example for such procedure.

There is hardly one field of science or engineering where mathematical methods have not been applied, and there is hardly one field of mathematics which has not been applied to science or engineering problems. A list of all these applications could have proved the important role of mathematics in modern research too. However, it is much more important to understand the fact that the world of mathematics is

the spiritual image of the real world. We understand then that the importance of mathematics in scientific and engineering research is far beyond that of mathematics as simply a tool. Mathematics is the soul of scientific research. There is hardly any human activity which can be more idealistic and yet more practical, more educational and yet more fascinating than to study and to teach the relations between those two worlds.

TODAY'S MIRACLES, TOMORROW'S NECESSITIES -- THROUGH ELECTRICAL ENGINEERING

by H. N. Muller, Jr.
Assistant to Vice President - Westinghouse Electric Corporation

My assigned duty - covering the part that electrical engineering plays in our society and the part that it will play in the future - is a tremendous task. This is so with each of the speakers at this Research Symposium, but perhaps electricity is even the most vast of the fields discussed during these two days. I believe this is really true in some respects at least, as I will attempt to demonstrate in my discussion.

Today in America we have installed industrial power equivalent to eight horsepower for every gainfully employed worker. Seven-and-one-half of these horsepower are made available by electrical energy. The tremendous advance in the use of electricity in America is demonstrated by the fact that in 1910 there were installed only 2.8 horsepower per worker, and over two of these horsepower were mechanical in nature, or were beasts of burden. This is the power that today provides, and will in the future provide, the productive capacity of American industry that is responsible in such great measure for our high standard of living and our relative security in an unstable and insecure world.

Another excellent index of our national strength is the installed electrical generating capacity in the United States. In the past six years, the nation's generating capacity has increased about two-thirds, at a cost, I might mention, of over six billion dollars. Looking ahead, we conservatively estimate that installed power generation will reach 165 million kilowatts by 1965. If it is recalled that our total national power plant was an even 50 million kilowatts just five years ago, this is a staggering increase in the energy available for productive industry. If one tries to picture the goods

and services that such a projected quantity of energy can produce, to conjure up even a rough picture taxes the imagination.

The rate of growth of the electrical manufacturing industry which produces the equipment that both originates and utilizes this tremendous source of energy is even greater. One decade ago this industry accounted for about 2% of the gross national product of the country. Today, the electrical manufacturing industry accounts for about 4% of the total measurable wealth of the nation, and this percentage will continue to grow. It is an elementary necessity if America is to continue to grow and prosper, and if we are to remain strong in the uncertain international picture. For any one industry to double its percentage of total American production in the ten-year period of our greatest overall growth, indicates phenomenal expansion indeed.

Thus, as I said at the outset, to present a well-rounded picture of this field is , indeed, a difficult task. I have selected a few particular areas of development that would appear to be immensely important to our future. I believe that being specific is always more clear, more convincing, and frequently more enduring than any attempt I might make to present our case through broad generalizations. The growth figures which I have already quoted are, in fact, my first specific example.

The tremendous rate at which all fields of technology are advancing dictates that research and development in electrical engineering be pursued with an exceedingly aggressive approach. Indeed, I have heard Robert E. Wilson, Chairman of the Board of the Standard Oil Company of Indiana, draw a striking analogy that vividly pictures the element of acceleration in our technical advance. The analogy postulates that we compress the 500,000 years in which man has been developing into fifty years, roughly comparable to our own productive lifetime. On this scale, it took man 49 years to get over being a nomad and to settle down to living in organized communities. It took him even longer to get

his first elementary items of manufactured clothing and many of the other things that we consider time-worn characteristics of man. It was only six months ago that a few men first learned to write in crude fashion, but on this scale, it was only two weeks ago that the first printing press was built. At the present rate of increase, it seems that in another two weeks, we shall all be buried under printed matter. Only within the last day have come such amazing things as radio, television, diesel locomotives, rayon, nylon, our miracle drugs, bookkeeping machines, electric computers of inconceivably complex equations, one-hundred octane gasoline, color and sound motion pictures, and the thousands of other modern products and services that we daily take for granted. On this same time scale, the first production of atomic power, of cortisone, the development of the hydrogen bomb and other military weapons came into existence since I made my introductory remarks.

I think it is perfectly clear that if this pace is to be maintained, it is the scientists and engineers who will have to maintain it. With the rapidly expanding part that electricity plays in our economy, supplying over 90% of our industrial energy, maintaining the pace hinges, in quite a measure, on electrical research and development.

I would like to point out that it is not possible to portray the part that electricity will play in America's future without cutting across several fields of science and engineering. For example, I have rather frequently been asked why it is that the electrical industry has played such a key roll in the development of atomic energy, right from the very beginnings of this new science. I have been asked, in effect, why our industry has played such a major roll when almost any of the industries interested in energy production or utilization might be pictured as having just as great an interest in the final results in the future. The answer is both simple and direct. With exceedingly few exceptions, there are no other industrial organizations possessing both the quantity

and extreme diversity of technical and scientific skills present in the the very large electrical manufacturing companies. In the research and development corps of these organizations rests the basic research background and the engineering know-how necessary to tackle a development job of such huge proportions. Another example of electricity's role in research can be found in the gas-turbine field, commonly known to the layman as jet-engine production, where actually the only electrical components are auxiliary and control devices. All the main development concerns mechanical and metallurgical technology. So, if my remarks refer to developments other than those purely electrical in nature, I must be excused. The electrical segment of our economy cannot be divorced from industry as a whole, and set aside to be examined as an entity in itself. With this bit of explanation, let us proceed.

The high frequency and ultra-high frequency areas in electronics have tended to make the headlines often in recent years through many spectacular contributions. However, if we are to be basic in our approach, the production of bulk power should receive our first attention, for this indeed comprises the muscles of America.

Your speaker's organization has recently accepted an order for two steam-turbine generating units rated 250,000 Kw each. Nowhere in the world are there electrical machines of this rating in existence, and to make the advance in design of these units even more spectacular, they will be 3600 RPM generators. I recall that a little more than one decade ago, engineers hesitated to tackle the design of 3600 RPM units of less than one-fourth this rating. Such a rapid change in the ability of engineers to design large power-generating units is based upon tremendous emphasis on <u>fundamental and basic research</u> in insulating materials, high temperature alloys, magnetic materials, and <u>applied research and development</u> in bearings, methods of heat transfer, etc. I can state with certainty that the ultimate in size, efficiency, and reliability of generating units is far from

reached. Larger units are already under consideration, and our continued research and development program guarantees that they will be produced just as soon as the power systems of America demand such giants.

At various times you have heard mention of other possible sources of electrical power. Among them, we hear of solar collectors, wind power, heat pumps, tidal energy, atmospheric electricity, etc. While these are all possible sources of power, most of them have been used only experimentally. As the availability of fossil fuels (coal, oil, gas) is reduced and their cost increases, some of these other forms of energy, fanciful as they may now seem, will unquestionably be developed.

Somewhat along these same lines is the field of atomic power generation. Today we see no way of converting directly from fissionable materials to electric power. In other words, to obtain usable power from an atomic reactor, we will go through some form of heat exchanger; then turbines and generators similar to those now known will comprise the electrical elements of the system. However, let us not rule out the possibility that some scientist will come up with a single idea, a basic one that will bridge this gap, making possible direct conversion from atomic fission to electrical energy. Some of our most practical research leaders do not envision this idea as fanciful, but rather just a matter of time and the appearance of the right young scientist with a fresh approach and a spark of genius.

What do we see when we look ahead at atomic power development? Right now, out in the western foothills of the Grand Teton Mountains in Idaho, there is a strange group of three buildings surrounded by knee-high sagebrush. The largest of these is a box-like structure in which has been assembled a full-sized submarine, complete except for bow and stern sections. Adding to the oddity, around the main section of this misplaced submarine is a huge tank of water, simulating the ocean this strange vessel will never ride.

All this is not without major purpose. Indeed, history is being made there at the National Reactor Testing Station. When the assembly has been completed, an engineer will stand before a control desk and turn a handle. When he does, a massive shaft will begin to turn, delivering several thousand horsepower into a power-absorbing waterbrake.

This will be an historic moment. It will mark the operation of the world's first atom-driven plant, built for the purpose of producing power in large quantities. It will be a milestone in the atomic age. Here at this desert location, the atom will be put to work for the first time to drive a plant intended solely to provide energy to turn machines to produce electricity, or to do other things requiring a continuous flow of power. To be sure, this power plant was built for a test submarine, but it could just as well turn electric generators supplying the current to light homes and to power factories.

Submarines are not going to monopolize nuclear power plants. Even before Westinghouse completes this first experimental job, work will be well along on the design of an atomic reactor for an aircraft carrier. This one will be many times largerin horsepower output than the submarine reactor. As a matter of fact, it will be of a size that could be considered quite practical for regular electric power generation.

No longer is there any question that the atomic broncho can be tamed to produce horsepower instead of holocaust. That power, furthermore, comes in terrific amounts. A wad of uranium weighing but a pound, if fully utilized, would be enough to supply the power needs of the state of Mississippi for quite a time. Just think of the implications this poses to both science and industry, and of the vast future possibilities!

Now, how about the means of controlling and using the energy that these future power ideas may produce? In other words, how will we make these new sources and amounts of energy, whatever they may be, do the work of producing

goods and services for an expanded economy in America? While it may come as somewhat of a surprise to some of you, it is here that the field of electronics should have its greatest impact on our future. Some of the future possibilities in the high-frequency field are fairly well known to most engineers, scientists, and businessmen through the tremendous application of radio, television, and other forms of communications. Much less public notice is given to the electronic applications used within industry, but it is here that electronics should make its greatest contribution to our gross national product.

In recent years the introduction of electronic circuitry for the control of complicated industrial processes has made possible tremendous increases in the production of steel, aluminum, paper, textiles, and many other basic commodities. The incredible accuracy of electronic control has accomplished this increase in production by greatly speeding up our rolling mills, our paper mills, etc. The reaction of electronic control circuits is so much faster and more sensitive than the keenest human mind or hand that complicated industrial production systems cannot only produce more goods, but the product is of more uniform high quality and, in many cases, much less expensive. In quite a measure, these electronic brains controlling industrial processes are giving us the answers we seek -- a future higher standard of living achieved through increased productivity to out-match our increased birth rate, decreasing death rate, and consequently, greater population. The emphasis on electronic research and development in industry has been increasing rapidly during the last decade and will continue to rise. Our engineers are confident that we have little more than scratched the surface in the application of industrial electronics.

But now a competitor to the field of electronics is already appearing on the horizon. This competitor, which promises in long range to perform many of the functions of electronic tubes, and to perform them more efficiently and permanently, is the field of semi-conductors. A tremendous amount of research

effort, utilizing a combination of electrical, metallurgical, and chemical talent, is being expended to learn more about semi-conductors and to make their applications practical and economical. Here we find a fascinating group of materials including selenium, germanium, silicon, and certain strange metallic compounds. These all have certain characteristics in common, and yet each of them is different. An important common characteristic is that in very pure, single crystal form, they have the unusual ability to rectify electric current with a very high degree of efficiency. By properly applying crystals of these materials, we are able to perform many of the functions of electronic tubes, not only very efficiently, but with unlimited life. If we are able to perfect the possibilities inherent in semi-conductor materials, we may go a long way toward performing the functions of electronic tubes with devices that are both permanent and maintenance-free.

One of these semi-conductor devices, the transistor, is doing for the electronics industry what synthetic fibers are for textiles - all that and more. It can do the job of most vacuum tubes, but it is much smaller than the vacuum tube, is practically indestructible, and takes almost no power from the circuit.

Right now it takes about a freight-car load of batteries every two days to keep an infantry division's electronic nerves alive. Substituting transistors for vacuum tubes, a suitcase full of batteries every two weeks would be enough, so the experts say.

The Army Signal Corps had a striking display at the Institute of Radio Engineers' Convention to show what the transistor can do for compactness - a Geiger counter that weighs only 1 pound, yet is capable of doing all the work of a vacuum-tube model that weighs 19 pounds.

We even envision semi-conductors invading the power rectification field to the point where, someday, today's well-accepted power ignitron rectifier could be completely superseded by silicon crystal devices alone! I can guarantee that the research effort in the electrical laboratories of America will continue at a

terrific pace toward solving the mysteries of semi-conductor materials.

Our first large-scale use of electricity was in the field of illumination, and while the growth of the electrical industry has been exceedingly diverse, illumination remains today, and will in the future remain, of signal importance. In the last few years, we have seen great progress in this field through the application of fluorescent devices to replace incandescent lamps for a multiplicity of every-day applications. Today we take for granted high intensity lighting for our homes, our offices, and our factories that could only have been afforded in a showcase or exhibit a few years ago. Fundamentally, this has been made possible because the perfection of fluorescent lighting gave us a source that produced more light per watt of energy consumed - in other words, it is a cooler light source.

Today's research on lamps and light sources not only is aimed toward better incandescent and fluorescent lamps, but looks much further ahead than that. I don't think anyone knows exactly what the future light source which will someday supersede fluorescence may be, but the field of electroluminescence is beginning to look promising. This is a fascinating phenomenon where sheets of translucent material, made semi-conducting through special treatment, glow when energized. The decorative effects that might be achieved through room lighting with electroluminescence, including chemical treatment to produce almost any desired color effects, are intriguing indeed.

The secret of theoretically perfect light is, of course, to achieve cold light. Perhaps someday, we will get as smart as the firefly and accomplish this result!

Much of what the electrical industry can contribute to our future depends upon metallurgical research. In constantly endeavoring to develop and design better apparatus and devices, we find that the physical and electrical characteristics of metals are usually the limiting factors. Thus, great emphasis

in fundamental research in the electrical industry is being placed on the field of metallurgy. For example, a major, full-scale research attack is being made on the fundamentals underlying alloys. By cut, and try, metallurgists have learned that when two or more metals are mixed in certain compounds, then processed in a particular way, an alloy of thus and such characteristics results. Just why, nobody knows. No one can predict, except in a general way, what properties a combination of metals, compounded in a given manner, will manifest. In short, metallurgists can not now design from theory an alloy to meet a specification. Our need for such knowledge is mounting daily in the electrical industry.

Precisely the same can be said for magnetic materials. Why it is that some materials are semi-conductors is a mystery, and the solution is urgently needed.

A fine example of one approach to some of these regions of mystery is by way of extreme cold. This is the field of cryogenics, where especially developed devices allow us to produce temperatures exceedingly close to absolute zero - the temperature at which all molecular motion ceases. Daily now, in our cryogenic studies, we are working with materials at temperatures as little as 0.1 degree above absolute zero. This would seem to be pretty cold if we remember that zero degrees Kelvin - absolute zero - is 460 degrees below zero Fahrenheit. Some amazing things happen to materials when subjected to this extreme cold. In many cases, both physical and electrical properties of metals change drastically in the temperature range just a few degrees above absolute zero. We expect to find out many things down in this region of unearthly temperatures. Mention of one or two may give a glimpse of what a cold-lab research man is trying to do.

Electrical resistance of a metal is, for the most part, affected by two things, impurities and temperature. At normal temperature, the temperature effect is so large as to mask the effect of impurity. But, at the threshold of absolute zero the temperature effect has almost vanished, leaving that of impurity standing sharply alone. Thus, impurities, which have great bearing on mechanical, electrical,

and optical properties, can be investigated with a hundred-fold greater accurancy. Fundamentally, what these men are after is an understanding of the behavior of matter. Why is it, they would like to know, that some metals such as cadmium, zinc, lead, mercury, and several others gradually dimminish in resistance, and then at some precise low temperature a few degrees above absolute zero, the remaining resistance disappears entirely? They become superconductors. A current, once induced in such a metal, if it is maintained in this temperature region, would never stop of its own accord!

Other metals, when that incredible boundary of absolute zero is approached, show a surprising increase in resistance. There is evidence that at absolute zero, the resistance of gold is infinite. (Just goes to show that gold in the world of science is as strange as in the world of politics!)

What good will come from poking around with materials at sub-sub temperature Frankly, if the research men knew, there would be no reason for the work. But they do know that under these conditions they can get a closer look at atomic and electric behavior than they can amid the confusing heat of our normal world. What a beautiful example of fundamental research this is! We do not know of any single product or service of the electrical industry that this work will directly benefit, but we are completely confident of the pay-off someday. We are sure that from the world of super-cold will come much of value for our ambient world.

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It is easy to go on ad infinitum when discussing the fascinating facets of modern research and development in the electrical engineering spectrum. This, of course, I am not licensed to do. I believe the several areas discussed should impart to you some glimpse of the breadth and depth of this field. I believe I can positively convince you of my company's tremendous faith in the future progress of electrical research and development by stating the following fact: In 1953 the Westinghouse Electric Corporation will spend more money, company-wide, on

research and development, than our total new profits for 1952.

Much of this, of course, is to improve or lower the cost of motors, transformers, light bulbs, and toasters. But as pointed out, large sums are going into investigations with less immediate results. In great measure, we stake not only our position in industry, but the security and well-being of future America on the long-range fundamental research program of industry.

In closing, I would like to recall to you the fable of the three stonemasons.

Once upon a time a man stood watching the construction of a large edifice. Scaffolding reached high and the ground was littered with huge blocks of stone. Workers were engaged in many tasks, but the most interesting of them all were three stonemasons.

The man watched them at work and then approached each of the three in turn. He asked the first stonemason, "What are you doing?" The tired workman wiped his perspiring brow and dully answered, "My job is to move these huge blocks of stone .... my superior tells me where to put one stone on top of another, AND THAT'S WHAT I DO."

He asked the second stonemason, "What are you doing?" The man looked up from his work, puzzled. "What am I doing?" he echoed. "Why, they're putting up a building here, and I'VE GOT A GOOD JOB LAYING STONE."

He asked the third stonemason, "What are you doing?" The artisan put down his tools and stood erect. Looking up to where the towering structure seemed to touch the clouds, he answered with simple dignity. "I", he said, "AM HELPING TO BUILD A GREAT CATHEDRAL."

The third stonemason typifies the vision, the challenge, the driving motivation of our men of engineering, working with inspired zeal toward greater achievement.

NATIONAL SCIENCE FOUNDATION
2144 California Street, N.W., Washington 25, D. C.

Research Symposium
Commemorating the Seventy-Fifth Anniversary
of Mississippi State College
April 24, 1953

Remarks by Dr. Paul E. Klopsteg
Associate Director, National Science Foundation

BUILDING SOLID FOUNDATIONS

Your Committee which arranged the program for this seventy-fifth anniversary celebration accorded me an honor and a privilege when it extended to me the invitation to make the keynote speech. For this distinction I express my sincere appreciation. With a privilege of this kind is associated a responsibility, which I construe to be that of sharing with you thoughts and ideas which may bear significantly on the subject of this symposium. It was my hope and expectation to be present to hear the distinguished participating speakers; but only a few days ago information came that the Subcommittee on Appropriations of the Senate would hold its hearing on the National Science Foundation budget on the afternoon of April 23. This delayed my coming by one day.

My first privilege and pleasant duty is to bring to you, Mr. Hilbun, and to your administrative officers and faculty, the felicitations of the National Science Foundation, upon having completed as a vigorous and growing organization the seventy-fifth year of the existence of Mississippi State College. I venture to add, though unofficially, the congratulations of my own institution, Northwestern University, which has made possible my service to the country through the National Science Foundation by granting me leave of absence. As you may know, the Technological Institute at Northwestern is also a vigorous and growing institution, devoted to teaching and research in science and technology.

You will understand, therefore, that I have had the benefit of first-hand experience with problems and conditions associated with an educational institution, in the light of which we may develop a rational philosophy regarding its position and its responsibilities as one of numerous similar institutions serving our people both locally and as a nation.

So that there may be no misapprehension, I must confess to you that before I was invited to come here, my information about Mississippi State College was quite limited. I knew that it is one of our land grant colleges; I knew that its name used to be, like that of similar institutions in other states, Mississippi Agricultural and Mechanical College. The change in name 21 years ago was undoubtedly the result of thinking forward towards expanding horizons.

It has given me satisfaction also to note the presence on your faculty and staff of people with advanced degrees from Northwestern, and from my alma mater, the University of Minnesota. My feeling of kinship is increased through my acquaintance with your former president, Dr. Humphrey, who is a member of the National Science Board.

Since the College is state-supported, it seemed desirable also to expand my knowledge about the state. It has been most interesting to do this. The result is that I feel much better acquainted with both the College and the state than I did several weeks ago.

Through my "library research" I have learned about the things that make Mississippi noteworthy as an important member of the federation of sovereign states that comprise our great nation. It must have been the traditional and true southern chivalry that caused the state legislature to make Mississippi the first state in the union to establish a state-supported college for women. You have the best State Museum in the country, and have created a veritable library of State history, through your unique educational and cultural State Department. Your budget for education has tripled in the decade between 1940 and 1950. In the

face of the long-continued and regrettable aftermath of the War Between the States, Mississippi is making an outstandingly successful effort to advance itself in education, industrialization and agricultural progress. It is in these three areas that this institution plays its very important part.

It is gratifying also to observe the increasing importance of the State of Mississippi and, indeed, of the whole South, in being chosen as preferred locations for many new, large industrial establishments. In the wake of industrialization there follow, inevitably, improving standards of living, which bring with them better education for more young people. Some of the industries are chemical, some are based on great agricultural productivity, others on the outstanding position of the South in having large forests, and the products derived therefrom. I note that Mississippi is one of the top-ranking states in the country in her forest crop. Without knowing specific facts, I should venture the guess that among the important activities of your college are research and development having to do with products in which the state excels--agriculture , forestry, chemistry.

Under the Morrill Act of 1862, it was one of the principal concepts that each of the states receiving grants of land should thereby be in better position to carry on the necessary educational and developmental activities suited to the special needs of the state. All of this is important, indeed it is indispensable, to establishing sound economic conditions within a state. The distinguished senator from this state, Mr. Stennis, ably argued this point in the Senate of the United States on April first, pointing out the benefits that had already accrued from federal support of research and development under the Research and Marketing Act of 1946, in the field of agricultural products. Under that act it was the intent of Congress to assure agriculture a position in research equal to that of industry, so that there might be maintained an equitable balance between agriculture and other segments of the economy.

The subject which I selected for this address, "Building Solid Foundations," is clearly an appropriate one, in that it provides a central theme for a discussion of questions related to what has already been said. It gives us a basis for considering what we might call the beginning essentials to achieving the kind of progress upon which our country depends both for its economic health and its security. Moreover, it provides the best basis I can devise for discussing with you some of the nation's needs respecting science and how they may be met. Thus it leads directly into a subject of paramount interest to me and of great significance to the nation's welfare--namely, the National Science Foundation, its purposes, aims, objectives and accomplishments and the manner in which these are related to the national needs; and how the successful achievement of the aims and objectives contributes to the building of solid foundations.

The word "research" unfortunately has many meanings to many people. The success of scientific endeavor in World War II was such that in the minds of many laymen the term became synonymous with working near miracles. The man on the street and the housewife could understand from the written accounts and the broadcasts that an atom bomb was thousands of times more powerful than any similar bomb previously devised. They could understand the reports, if not the technical details, about proximity fuses which did not require impact to detonate a shell or a bomb, but caused detonation if the missile approached its target within some predetermined distance. These and many other examples that were described in popular journals and newspapers after the war convinced the average reader that science could do anything, and that scientific research was responsible.

It is a fact also that the average buyer of goods that contribute so much to the comforts and conveniences of living accepts them without knowledge of or interest in the long, difficult road that had to be traversed to make them available for public use. To the layman research possibly means the development and engineering that precede the production of such items because, of course, it takes a

a great deal of that kind of thing to get them on the market. It may mean nothing more than gadgeteering. However, what precedes development and engineering, namely basic research, is to the average layman a closed book. The word "research" for him does not include any part of the mental effort and other activity comprising basic research. I am thoroughly convinced that fuller understanding and appreciation are needed by the layman of the meaning of basic research, of the methods used by scientists, and of the necessity of enlarging our knowledge of nature. Well-planned methods must be put in practice by which such understanding and appreciation can be brought to the large, intelligent lay public that is not particularly concerned with science. Its importance derives from the fact that in this technologic age, and in a country so dependent on science and technology, our citizens should have some concept of the impact of science on their livelihood and their security. In our country particularly, where science is the very foundation of our material existence, should not science become as much a part of, and permeate, our culture as any other segment of learning and knowledge? Is not science as much a creation of the human mind as are the humanities and the arts? Should we not be thoroughly aware of the fact that however science is used, its uses are also conceived by the mind, that science itself is impersonal and that it is only the uses made of science that have either auspicious or sinister implications?

It is highly desirable indeed that the meaning of the word "research" be restricted to the general activity of pushing back the boundaries of ignorance rather than having it overworked in the advertising of cigarettes, tooth pastes, deodorants, shampoos and the other products that now occupy so much time on television screens and the radio.

Most fundamental of all, as we think of the nation's needs, is recognition of the fact that basic research as we know it is primarily, if not solely, the function of our colleges and universities, and, more specifically, a part of the normal activity of faculty members in our many great institutions of higher learning.

To be sure, there are a few of the large industrial concerns that operate extensive laboratories principally for the practical development work needed by the commercial organizations. In these some basic research is done on the periphery of the principal activities of the laboratories. This is laudable, for we need all the basic research that can possibly be done, since the widening of our horizons and the increasing of our knowledge must go on to the limits of our creative ability. However, it is not a primary activity for an industrial establishment to carry on basic research. Its function in the main is quite different and it would be difficult for a Board of Directors to justify to its stockholders much of this kind of work. If you ask how much basic research should be done the answer I would give is, "as much as can be done by the competent scientists available to do it." This, in the light of my earlier remark, means that the amount of basic research that will be done is primarily that which the able scientific staffs in our colleges and universities will undertake to do; and it means that our able scientists must be given the opportunity to engage in research as well as in teaching.

It was such considerations that engaged the thinking of our leaders in science towards the close of the war, and it is interesting to note the results. In the American annals of science, there is an outstanding document which promises to preserve its stature as one of the most important ever published, from the standpoint of setting forth the nation's needs in science. I refer of course to the Bush Report to the President, published in July 1945 with the title, "Science, the Endless Frontier." Many of you will remember it, and recall the effect it had in directing attention to the things the government should undertake to restore quickly the dislocation that had been forced by the war upon the scientific community, and that had so completely warped its normal endeavors. The Report was based on studies and findings of four committees: the Medical Advisory Committee; the Committee on Science and the Public Welfare; the Committee on Discovery and Development of Scientific Talent; and the Committee on Publication of Scientific

Information. It made a series of recommendations which comprised the first set of concrete suggestions, the adoption of which would constitute a national policy respecting science. One of the major recommendations was that there be established a National Science Foundation, having among its purposes to:

> ..... develop and promote a national policy for scientific research and education, ... support basic research in non-profit organizations, ... develop scientific talent in American youths by means of scholarships and fellowships, and .... by contract and otherwise support long range research on military matters.

This far-sighted document became the incentive for the introduction of legislation in the 79th Congress which, after a protracted legislative period, eventuated in the National Science Foundation Act of 1950. After passage of the law, in May of that year, seven months elapsed before the National Science Board of 24 members, provided in the Act, was appointed by the President. The Director was appointed in April 1951. The Foundation as an operating agency is, accordingly, two years old. In the meantime, the Korean War had begun, which undoubtedly diverted attention and interest from the Foundation, and focussed them upon the requirements of the immediate emergency. Again the needs of the future were considered the concern of the future. It is always difficult to persuade people about the urgency of doing things that may have great importance five, ten or more years hence; and this becomes especially difficult in time of military action, or preparation for war.

The Act recites as functions of the Foundation essentially the objectives enumerated in the Bush Report. The importance of "Science, the Endless Frontier" is well worth noting here, not only because the National Science Foundation Act

was a consequence of its publication, but because it comprises the first set of suggestions, systematically developed, as to what a national science policy should be. The report noted that there was no body within the Government charged with formulating or executing national science policy, and recommended the establishment of a new agency charged with the responsibility.

Let us now look at the first function of the Foundation, namely that of developing and encouraging the pursuit of a national policy for the promotion of basic research and education in the sciences. This is not only the most important but the most inclusive also. Obviously the establishment of the Foundation by congressional action was itself an Act constituting national policy, asserted and confirmed at the highest level of authority. Thus, it is part of national policy to have an agency in the Executive Branch of the government, responsible for certain activities designed to strengthen the nation in science. The various other functions recited in the Act, which the Foundation is authorized and directed to undertake, are likewise a part of national science policy, also adopted and stated as such by the Legislative and Executive Branches of government.

Without going into details of the assigned functions, let me briefly enumerate them.

Within the over-all national policy function, then, the Foundation is authorized and directed to carry on in the following important activities:

(1) Initiate and support basic scientific research in all the natural sciences -- biological, medical and physical. Wide latitude is provided in the manner of giving this support -- by contract, grant, loan, and other methods.

(2) Award scholarships and fellowships in the sciences.

(3) Appraise the impact of research upon industrial development and the general welfare.

(4) Foster the interchange of scientific information at home and abroad.

(5) Evaluate research programs of government agencies.

(6) Correlate the Foundation's programs with the research of other agencies and individuals.

(7) Maintain a register of scientific and technical personnel, and in other ways provide a clearinghouse for personnel information.

(8) At the request of the Secretary of Defense initiate and support research having military implications.

The Act specifies the administrative and operating structures of the organization. The twenty-four members of the National Science Board and the Director are appointed by the President and subject to confirmation by the Senate. There is a Deputy Director and there are four Assistant Directors, the latter in charge of the Medical and Biological Sciences; the Mathematical, Physical and Engineering Sciences; Scientific Personnel and Education, comprising the responsibility for scholarship and fellowship awards and for the National Register of Scientists; and the administrative functions of the Foundation. In addition, there is a general counsel and his staff; a scientific information office; and a program analysis office. These are not prescribed in the statute, but were established by the Foundation.

Each of the operating divisions also has a statutory divisional committee appointed by the Board, which has general advisory functions in connection with the work of the divisions.

The general authority of the Foundation is flexible. Within broad limits it can do whatever it deems necessary to promote the progress of science. The Act recognizes the importance of both research and education in bringing about this progress. The Foundation may not itself operate or own laboratories. Thus far, financial support for research has been provided through grants which, insofar as is possible in a government agency, are handled much as grants are handled by

a private foundation. In contrast with the contracts that were developed under the Office of Scientific Research and Development, the grant reduces the financial support of research to the utmost simplicity.

Each recommendation for a grant must be approved by the National Science Board. Having been so approved the recipient of the grant--usually a university or college--receives a one-page letter from the Director, which states in simple language that the institution has been awarded the grant for the support of the research of Professor Blank. The duration of the grant may be up to five years. The letter also specifies the simple terms to be observed. If apparatus is purchased or constructed, this is at once the property of the institution. There is no property accounting, nor maintenance of annual inventories. The money is paid in advance, usually in installments. It may be disbursed by the university like any other departmental account. There is no renegotiation, but the account is subject to friendly audit to assure that it is being used as originally intended. Once the grant has been made it is the responsibility of the university to administer it so that the research to be done is carried on in the most effective way. Should the principal investigator for any reason be unable to complete his program under the grant, the uncommitted and unspent balance is returnable to the Foundation.

Thus, the building of solid foundations for the future economic health and security and general welfare of our nation is provided for by the creation of the National Science Foundation. The mechanism has been set up, is operating and is ready to operate on the greatly enlarged scale that is required if the nation's needs are to be adequately served. Through its operation -- provided there is sufficient financial support by which it may be enabled to perform its several functions -- it may render assistance to our universities and colleges towards becoming increasingly the important source of new knowledge in science; and towards identifying and training the able youth of the nation to play its part in both creating and applying such knowledge.

We should clearly distinguish and maintain the distinction between the kind of research normally done by a university faculty and the research and development procured by such government agencies as the military departments and the Atomic Energy Commission. The former, I repeat, lies within the sphere of the university's normal responsibility. The latter is a public service function, for which a university alone determines the extent of its obligation. If it considers that it has the competence in the way of facilities and personnel, no one other than the university authorities themselves has the right to say whether or not the institution should undertake such work. It is their own affair to decide whether such work would desirably contribute to the normal functions of the institution.

Many university administrators look with some misgiving, not to say apprehension, on the great volume of development work undertaken by the universities under contract with government agencies. They note that this inevitably results in diversion of competent scientists from their normal scholarly activities to administrative duties and to directing programmatic studies, with the result in many instances that a research scholar is permanently lost to basic research. Moreover, the intensity of developmental activities in the universities, in other non-profit establishments, in government laboratories, and in the industrial laboratories creates salary competition that the universities find it hard to meet. The consequence may well be a serious deterioration in the quality and quantity of basic research produced in the universities. The question is under serious study by university administrators.

In considering this question we must not overlook the fact that the scientists and engineers required by industry can come from only a single source -- namely, the universities. Ways must be found to increase the output. We must look seriously at the fact that our technological industries are doubling in size every ten or twelve years. To maintain anything approximating this rate of increase requires production of competent scientists and engineers at somewhere near the

corresponding rate of increase. The present rate of growth of our Nation's population is a doubling in seventy-five years. Clearly, it is necessary to increase the ratio of young people who are to be trained in the sciences to the total population. It means also that the rate at which we produce basic knowledge must increase in the same or greater ratio.

Among the various activities prescribed in the Act, the Foundation has been able to make excellent progress during the two years of its existence, within the limits set by restricted funds. It is supporting some 575 postgraduate fellows, selected rigorously on a competitive basis. It has thus far not been possible to provide undergraduate scholarship aid, although this is important in the manpower problem. Perhaps most important is to find and identify the young people in high schools who are capable of becoming scientists and who have an interest in science. This is being studied. In its various activities the Foundation is fortunate in the help it is getting from leaders in the sciences, serving as consultants. Its scientific information and program analysis offices are active in their respective assignments, the former in providing emergency aid for scientific publication, for translation of Russian scientific literature and compilation of a Russian dictionary of scientific terms, and making grants for aid to official delegates in attending international scientific conferences; the latter in gathering and analyzing the data needed to learn the nature and extent of government support of research and development, and to provide the basis for other reviews and appraisals. Activities in connection with the register of scientific personnel are also well under way.

As you permit the magnitude of this task of adequately meeting these various responsibilities to make its impact upon your thinking, you become aware of the magnitude of expenditures that must be made to reach whatever reasonable goals may be set. You realize then that although the amount of money spent by government currently for basic research and training in the sciences in our universities and

other non-profit institutions amounts to about $70 million annually, the agency that is specifically charged with the fostering of basic research and the associated training in the sciences currently has the disposition of about 4% of the total for this purpose. You realize, particularly if you happen to be a member of the National Science Foundation staff, that the disbursements required to carry on the functions prescribed cannot be made unless somehow you first obtain the funds to be disbursed for these purposes. You note that the Act has written into it a ceiling of $15 million annually for all of the functions. Your concern grows as you note that during the first two years of its active existence the Foundation has had $3.5 million and $4.75 million respectively. You note with great concern the difficulty of communicating the full import of all these things to those who are charged with the responsibility and authority for providing the funds. You hope that to the greatest extent possible industry may also realize the serious implications of the facts stated and that industry will help the universities to engage in their normal research and to increase their output of competent scientists and engineers, but you realize also that it will probably be a long time before industry takes over an appreciable part of this responsibility. In the meantime the responsibility rests squarely on government.

To bring you the latest information about the prospects of the Foundation in fiscal year 1954, I may report that the Bureau of the Budget, in this year of pressure on budget reductions, approved 12\frac{1}{4}$ million of the $15 million requested. This is strong evidence of recognition by the Executive Branch of the importance of the Foundation's objectives. Moreover, in support of the 12\frac{1}{4}$ million, the Director of the Budget indicated that the amount of the increase over this year's appropriation is more than accounted for by decreases in justifiable requests for similar purposes by other agencies. Thus it is made clear that there is no over-all increase, but rather a decrease. The administration's policy is to centralize the government's programs for the support of basic research in the National Science

Foundation, but that other agencies will be allowed to support basic research directly related to problems for which they have statutory responsibility.

Within the past few days, the House has taken action of recommending $5,724,400. This was not unexpected, but it is not too discouraging, since it represents an increase of $974,400 over the Foundation's appropriation for 1953, the present fiscal year. We look hopefully towards action by the Senate. There is evidence of increasing understanding in the Legislative Branch of the nation's needs, and of its desire and intention to do what is require to meet them. An example of this understanding is the bill introduced in the Senate by Senator Alexander Smith which provides for the removal of the $15 million ceiling written into the original Act. The companion bill has been introduced in the House by Representative Wolverton. These have the support of the President. All of this is a solid basis for optimism.

I am happy to report also that within its limited means of the past two years of its operation, the Foundation has been able to provide grants supporting three excellent research projects in this state, one of which was made to State College, with Dr. L. C. Behr as the principal investigator. It was also able last year to award one fellowship for graduate study in Mathematics, to Edward E. Grace, of Corinth, and to continue this award for another year; and this year, to make an additional award for graduate study in Agriculture to Jesse L. Fletcher, of State College, part of whose undergraduate work was done here. Moreover, in addition to the fellowships granted to applicants from Mississippi, there were two honorable mention citations: to Robert L. Rutledge, of Sandersville, and James H. Long, of Jackson, who attended State College. When you consider that applicants for both grants and fellowships are competing with some of the best in the country, and that awards are made on the basis of excellence and merit, the record I have cited is one in which those concerned may take pride and satisfaction. It gives encouraging promise for the future.

From what I have so inadequately said, I hope that I may have succeeded in establishing in your minds some picture of my own thinking about our needs, and about the means we may employ in establishing our foundations more solidly, so that the structure of technology, by which we promote our welfare within the state and as a nation, may grow soundly and substantially. My task of making preparations to appear before you, and to share these ideas with you, was a most pleasant one. It has been enlightening to me, and I shall be returning to my regular labors with the appreciation that comes from better knowledge and from the kind of understanding that can develop only from personal associations.

May I again express to you my great satisfaction for the privilege of addressing you, and my best wishes for the continuing progress of this fine institution. May all of you who are associated with it, and who are responsible for its administration and for its great mission in teaching and research, find new inspiration and new enthusiasms in this anniversary celebration to move towards new accomplishments of service to the increasing numbers of people for whose benefit Mississippi State College was founded seventy-five years ago.

STRUCTURAL ENGINEERING LOOKS AHEAD THROUGH RESEARCH

By Mace H. Bell
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It is indeed an honor and a pleasure to take part in this "Research Symposium," arranged in commemoration of the Seventy-fifth Anniversary of Mississippi State College. Each time I have visited State - and these visits have been at too widely separated intervals since my graduation some twenty odd years ago - I have felt a thrill of pleasure to see new buildings and signs of growth everywhere. These are visible evidence of the increasingly important part that the College, with its classrooms and laboratories, is playing in the development not only of Mississippi but of the entire South, my native region. I am glad to be home once again!

Research is a very vital factor in keeping our country, our industries and our entire economy strong, sound, and healthy. You have heard from our speakers of yesterday of the fruits that constant striving on the part of many thousands of physicists, chemists, mathematicians and engineers has borne in several fields.

The fruits of research and engineering development are evident all over Mississippi, everywhere you turn. When I was a boy, the Delta north of my hometown of Vicksburg depended on manpower, mules, and richness of the land to raise their staple crop - cotton. Today, manpower is used more efficiently, machines have replaced the mules; and huge quantities of chemical products are used to enrich the soil, control insects and plant diseases, and as a result, to increase the productivity of our lands to meet an ever increasing demand.

It used to be a major undertaking to drive from Vicksburg to Starkville by automobile in those days. Our roads were of gravel, narrow in width, with many tortuous curves and steep grades in the hill country. Our bridges were inadequate -

too light for heavy traffic. Sometimes our streams flooded the low lands, delaying a journey for hours. Today, aided by the knowledge, materials, and equipment put into their hands through research, civil engineers have made that same trip possible in a matter of a few hours. Our highways are wide ribbons of smooth pavement, our new bridges, designed to provide adequate clearance and capacity for all traffic, vault high above the waters of our streams. The streams themselves are checked against uncontrolled floods by levees, channel improvements, storage reservoirs and other means.

A quarter century ago, Mississippi was primarily an agricultural state. Industrial development was limited in extent, and products were few in number. Today, new factories are springing up all over the state; products that were unknown, and processes that were undreamed of are the basis of much of this growth. Our young men of today, such as the fine student body here at State, take these as relatively commonplace - natural gas transmission, television, super-sonic speed planes, 60 mile an hour highways, atomic energy - yet many here can remember the wonder they felt when such development first came into being. Research, scientific exploration, engineering development, together have made these things possible.

I have touched very briefly on some of the changes that have come about in recent years. Now, I must tell you of the progress that has been going on in structural engineering! The discoveries that have been made, the improvements and changes that have been wrought in our bridges and buildings, are perhaps not as spectacular and dramatic as nucluear fission, with its dual possibilities for terrible destruction and unlimited power - yet, they have contributed much to the development of the huge factories and plants that house the industrial might of this country. They have had definite effects on the appearance, serviceability and life of our bridges. They have brought noticeable changes in the appearance, usefulness and economy of the many types of buildings and other structures required by the demands of today's civilization.

Here too, research has played an important part. Such changes have not come overnight. Instead, through constant study and continuous activity on the part of many research workers, mathematicians, engineers and professors, new approaches, new materials and new methods have been evolved. The present state of the arts of structural engineering and construction cannot be credited to one group, or even a few. It is the result of the work of many individuals and organizations that are connected with the very large field of structural construction.

The developments, changes and improvements that have been made in this field make a story that is entirely too long to recount here. I shall therefore try to tell you specifically of some of the more important happenings that have come about in the one part of that field with which I am best acquainted - structural steel construction.

Perhaps I should digress here for a moment to tell you briefly about the American Institute of Steel Construction and what it does! It is a service organization, a trade association, representing the structural steel fabricating industry in the United States. It operates as a nonprofit organization, supported by dues paid by some 289 individual member fabricating companies who handle over 80% of all structural steel work going into bridges, buildings and other framed structures in this country. Founded in 1921, it has been dedicated to the following purposes:

1. To increase the fund of useful engineering knowledge and to promote the science and art of steel construction through technical research.
2. To stimulate through cooperative effort, efficiencies and economies in the design, fabrication and erection of structural steel.
3. To disseminate all such information, and to assist in its application through a staff of engineers.

4. To promote the growth of the industry by expanding its possibilities and its markets.
5. To collect and publicize statistical information.
6. To foster improvement of conditions and business relations within and without the industry.

It is of interest to note that three, or one-half, of these primary objectives are directly concerned with research, and the engineering application of information so obtained to practical problems of steel construction.

The Institute does not maintain a research laboratory of its own. Our policy has been to cooperate with other vitally interested organizations and governmental departments in sponsoring both experimental and analytical investigations. The greater part of this work is currently being carried out under the direction of several research councils whose membership and financial support is drawn from their sponsoring bodies. The actual laboratory work, analysis of data, and preparation of technical reports are handled by individuals associated with the laboratories conducting the work.

In some cases, where a field of investigation has been limited in extent, of a nature that is not within the scope of an existing council's broad fields, or of interest primarily to the Institute - we have sponsored other experimental investigations through various arrangements using the facilities and staffs of laboratories at individual colleges, at the National Bureau of Standards, and at companies which maintain their own research departments.

Some insight into the scope of structural investigations being carried on in the field of steel construction can be gained by a brief resumé of projects now underway under the direction of four different Research Councils. The membership of these councils is made up of individuals drawn from the ranks of engineers, scientists and educators, and represents the top talent that can be assembled. The councils serve to give guidance and direction to the various programs undertaken,

and contribute their varied knowledge and talents to the most effective solution of each project. As one of their sponsors, the Institute, in collaboration with other vitally interested organizations and governmental departments, is currently interested in experimental and analytical investigations at a dozen American engineering colleges and at the Mellon Institute of Industrial Research. Briefly these councils include:

The Welding Research Council, which under the supervision of its Structural Steel Committee, has programs of investigation to determine the behavior of welded continuous frames and their component girders, knees, and columns, loaded well into the plastic range.

The Research Council on Riveted and Bolted Structural Joints, first organized in 1947, which is active in obtaining a better understanding of the actual behavior of structural joints assembled with either rivets or bolts. Its overall program is divided into a number of separate projects covering investigation of the following: effect of rivet bearing on static and fatigue strength of plates; effect of rivet pattern on static strength of joints; strength of rivets in combined shear and tension; strength of bolted structural joints; effect of grip, connection pattern, and high-strength steel on the fatigue strength of joints, both bolted and riveted.

The Column Research Council, which has projects underway that at the present time include: investigation of residual stresses in columns in structural frames; the effect of initial eccentricities in columns; the buckling of rigid joint structures with special consideration to columns; inelastic stability; lateral buckling of beams; column interaction formulas; and stability of bridge chords without lateral bracing.

The Steel Structures Painting Council, that is, as its name implies, concerned with the surface preparation and painting of steel structures. Its work is directed to the investigation of existing methods, and the

improvement of procedures and materials. In addition to its research work, it has underway the preparation of a series of specifications covering surface preparation and painting, and the compilation of a complete Manual of Painting Practice.

In the past two decades the engineering profession has developed new methods and improved on older procedures, used in analyzing the stresses in structural frameworks and in designing members and connections to resist these stresses. Aided by time-saving methods, and such short-cutting devices as charts, tables and graphs developed through theory, research and model testing, the structural engineers of today do not hesitate to take full advantage of the economies that can be achieved through use of new knowledge as it is made available through research.

These advances in engineering knowledge, paralleled by advances in steel fabricating techniques, have given the structural engineer opportunities to use greater imagination and ingenuity, together with sound judgement, to achieve improved and advanced designs for today's bridges and buildings.

What are some of the practical results that have come about? What is meant by the terms - "rigid frame knees," "continuous frames," "the plastic range"? These are questions that probably occur to you.

First let me tell you of some of the practical results that such programs have brought about in our present-day structures.

We are all familiar with one or more of the usual truss-type bridges that span our larger streams. Other than the very obvious facts that they have wider roadways and appear to be built more strongly than early bridges, what is different about them? Well, many of the older bridges were designed with tension members of flat "eye-bar" type, and compression members of hollow box shape built of angles, plates and lacing bars. These members were then pinned together with large cylindrical pins to make the familiar triangular pattern that forms the outline of a truss bridge.

Today the members of our bridges have changed completely in appearance. The so-called "eye-bars," flat pieces of steel with a single large hole in each end, the built-up box member with its pattern of zigzag or X-type lacing, and the large pins are infrequently used for main truss members. Instead, bridge engineers use members that in cross-section look like the capital letter H, or like rectangular boxes. These frequently consist of a single piece of steel, rolled to a shape called a Wide Flange section, or they are built up with various combinations of angles, plates and perforated cover plates. The pinned truss joint, with few exceptions, has been replaced by riveted connections.

The substitution of rolled sections, of perforated cover plates with access holes in lieu of lacing, and of rigid riveted joints have all contributed a great deal to the appearance, the strength, and economy both in first cost and in maintenance costs of steel bridges.

The perforated cover plate perhaps offers a typical example of a specific result of research. Heavy bridgemembers built up of many component pieces must be adequately tied together to prevent local buckling of their parts, at the same time means of access to their interiors, for inspection and repainting, must be provided. As the outgrowth of a research program conducted at the National Bureau of Standards, it was determined that the net area of perforated cover plates can be included with the area of the main component parts, in proportioning a member for axial stress. As a result, this type of member is quite frequently seen in our new bridges.

Riveted connections have been used in both bridge and building construction ever since steel and iron came into common use as a structural material. For a long, long time certain rules, established many years ago, concerning proportioning of such joints, were followed without major change. In recent years, investigators found that some of these rules were very conservative, had little basis for their existence, and were in need of revision or modification.

Out of a wealth of data and information on the actual behavior of riveted joints, accumulated by many independent research investigations and more recently by joint effort under guidance of the Research Council on Riveted and Bolted Structural Joints, have come new rules that are more nearly in accord with the actual behavior. Today we permit higher bearing values, we accord rivets in direct tension the same allowable stress as that permitted in connected parts, and we have developed rules for proportioning connections, where rivets carry combinations of shear and direct tension.

Although the use of bolts has been recognized for many years, it has been customary to use lower working stresses and hence more bolts to do a given amount of work in a connection. Other limiting factors, dictated by specification provisions and by experience, have until quite recently restricted the fullest utilization of bolts in structural work.

The use of high-tensile steel bolts, prestressed to a tension such that friction between the connected parts transfers the stress from one member to another, is one of the outstanding developments that have taken place within the past five years. Investigations conducted under the sponsorship of the Research Council on Riveted and Bolted Structural Joints, culminating in the issuance of a specification, have stimulated interest in, and acceptance of, this type of connection in both bridge and building work.

In bridges and other dynamically loaded structures, the superiority of high prestressed, high-strength bolts has been proven both by laboratory investigation and by actual field test installations. Few building connections are subject to the dynamic loading and vibration that occur in bridge construction. Nevertheless, the use of high-strength bolts for field connections has much to offer and is gaining wide acceptance and use today.

Soon after the issuance of the Council's Specification on the use of high-tensile bolts in January, 1951, the A.I.S.C. in April of that year endorsed it as

representative of good practice. Less than a year later, the American Railway Engineering Association adopted, in March, 1952, identical specification provisions, thus permitting their use in railway bridges.

The story of progress and development in the use of structural welding goes back some twenty-odd years. It was not, however, until after the close of World War II that this method of joining structural steel came into its own. Its increasing use can be credited to a number of factors, chief among which are the training of large numbers of competent welders; the development of welding equipment and electrodes to a high degree of perfection; the close cooperation by engineers, equipment manufacturers and fabricators in developing ways and means to do a better job at less cost in time and material; and, last but not least, the improvement in materials, methods and procedures brought about by metallurgical and structural research.

There are very important differences between a well-executed welded design and its riveted or bolted counterpart. In welding, for example, the various elements of a framework are often joined together with a minimum of connecting detail material. Gusset plates of trusses are frequently eliminated, but welds replace plate and angle wind connections, and plates replace angles as stiffeners for webs of girders. A welded connection is usually designed for the particular load that it must transmit, since there is not the same need to standardize detail parts as is the case in riveted work.

In the structural field, welding has had much more extensive growth in its application to buildings than in bridges. There are various reasons for this, a detailed discussion of which would take more time than is available. It is sufficient to say that welding has been used successfully in both types of structures. The American Welding Society has established detailed requirements on qualification procedures, inspection and workmanship, material requirements and so on in separate specifications for buildings, and for bridges. From time

to time, as new knowledge has been gained through research and experience, these requirements have been modified in the light of that knowledge.

The A. I. S. C. and various bridge authorities recognize welded fabrication and cooperate closely with the American Welding Society in keeping its specifications and standards up to date as research, improvements in materials and fabricating techniques, and the development of new methods and assemblies have dictated.

The steel truss and column framing commonly used in gymnasiums, hangars, industrial buildings and the like is familiar to everyone. In recent years a new type of framing for these structures has come to the fore. It is the so-called "rigid frame," consisting of columns and girders rigidly fastened together at the roof peak and at the eave line by special parts that are called "knees." Design of the columns and girders offered no particular problem to an engineer, but until recently nothing was known of the stress distribution in the "knees."

Data obtained from large scale model tests conducted at the National Bureau of Standards, and at Lehigh University, were used in the development of a theory of analysis of the problem that serves as the basis for the design of these knee sections today.

Perhaps one of the most far-reaching and outstanding developments in the entire field of steel framed building construction is that commonly termed "light-weight construction." In essense the term means that every pound of dead-weight not necessary in the construction of a top-quality, fire-resistive structure, has been eliminated. This construction, particularly suited to the great number of multi-story buildings rising in our cities for offices, hotels, apartments, hospitals and the like, represents the results of research in many fields. It is not a development that can be credited to steel research alone, for it represents the integration of much research and development work by many allied industries in the construction field.

Not too many years ago, steel framed buildings of the highest fire-resistive rating had each column and beam individually encased in heavy masonry concrete, brick or tile. The framework was further subjected to heavy dead-weights of concrete, on the arch floor systems and various forms of exterior masonry walls, usually of 12-inch minimum thickness.

Today, the same fire rating is achieved by use of a light-weight fire-resistive plaster, placed to form a ceiling under the floors and an envelope around each column. This protection also serves the dual purpose of providing much of the interior finish. Today, steel floor, roof and wall elements, combined with light-weight concrete and various insulating materials, have taken the place of the heavier masonry construction, resulting in lighter and more efficient floors and thinner and more effective walls. The dramatic weight reductions, achieved through these combinations, result in larger overall economies in the costs of a structure, and they entail no sacrifice of quality, strength, or fire resistiveness in the structure.

Until very recently, practically all multi-story steel framed buildings have been designed with one concept of action under vertical loads, and with an entirely different concept for horizontal loads due to winds, earthquake forces, and the like. This is somewhat of a contradiction that has been difficult to justify in the minds of precise stress analysists. Yet, the assumptions have many valid and practical reasons that have resulted in a continuance of the practice to this day.

A typical framework for such a building consists of a series of connected wind bents, each made up or rows of vertical columns, with horizontal lines of girders at the floor levels. The girders are connected to the columns in such a way that they can support vertical loads and at the same time resist horizontal wind forces that tend to make the building frame distort out of its true vertical position.

Recognizing the fact that as the girders deflect under vertical loadings, their end connections are subject to stresses similar to those caused by horizontal loadings, the Institute Specification was revised some years ago to permit three

basic types of design under certain stated conditions governing the size of members, and types and strength of their connections. These are:

Type 1. The "rigid-frame," which assumes that end connections of all members have sufficient rigidity to hold virtually unchanged the original angles between the connected members.

Type 2. "Simple framing," which assumes that the ends of beams and girders are connected for shear only and are free to rotate under load.

Type 3. "Semi-rigid framing," which assumes that the connections of beams and girders possess a dependable and known moment capacity, intermediate in degree between the complete rigidity of Type 1, and the complete flexibility of Type 2.

This recognition that the members and connections of a structural framework are subjected to varying stresses and strains which are dependent on their proportions and stiffness, regardless of what theoretical assumptions a designer may have made, has led to a great deal of research on the actual behavior of "semi-rigid" and "continuous" framing.

An extensive program of tests of various beam-to-column connections, including wind connections made up of angles or split-T's and web-framed connections, typical of those commonly employed in multi-story building work, in combination with these, was undertaken at Lehigh University. The degree of end restraint afforded by such connections over a wide range of application was experimentally determined. The data and information obtained were then used to develop a recommended design procedure which enables the engineer to take full advantage of the economies that can be achieved in proportioning main members joined by "semi-rigid" connections, with full assurance that they will perform as he intended them to.

Another even more recent change in the specification affecting "continuous framing" is of great significance to structural engineers today. It points the

way to an entirely new concept of structural design already in use in England and under research and development in this country.

The change to which I refer is encompassed in two provisions that permit a 20% increase in the permitted bending stress used in proportioning beams and columns of continuous framing. The conditions under which this increase is sanctioned are based on considerations of the behavior of continuous framing and of the actual behavior of the ductile material, A-7 steel.

A comparison of the critical design bending moments for two adjacent uniformly-loaded simple-span beams of equal length and a beam similarly loaded but continuous over both spans, indicates that both would fail at the same loading. This is a comparison that Ripley's "Believe it or Not" featured some years ago. Nevertheless, in the case of steel, the ultimate load-carrying capacity of the continuous beam is much greater than that of the two simple-span beams.

Continuous beam-analysis is not the simplest thing in the world, so to visualize the action that takes place when framing is made continuous let's consider the problem of two uniformly loaded single spans, one simply supported, the other with fully fixed-ends. Let's assume that no additional load can be placed on either beam without complete collapse when the extreme fibres resisting the positive bending moment <u>at the center</u> of their spans have reached a yield point stress of 33 k.s.i. Let's also assume that after the extreme fibres at the restrained ends of the fixed-end span have reached yield point stress of 33 k.s.i. they will continue to carry that stress, but will yield plastically in much the same manner as will a steel bar in direct tension.

Since conventional design procedure requires that the simple span be proportioned for a bending stress of $\frac{WL}{8}$, and the fixed-end span for $\frac{WL}{12}$, we will select beams with bending resistance capacities in the ratio of 3 to 2 for the two systems of framing. Hence, in both cases the same load will produce the same extreme fibre

stress - in the first case at mid-span and in the second case at the restrained ends.

Now let 's add loads to each span until the center-span extreme fibre stress in each reaches 33 k.s.i. Up to the point where the extreme fibre stresses at the restrained ends of the fixed-end beam reach 33 k.s.i., the moment produced by its increased loading will be distributed 2/3 to the ends and 1/3 to mid-span. At this stage of loading, then, the mid-span fibre stress is one-half of 33 k.s.i.; yet this same total applied load will cause collapse of the simple span.

Let's continue to apply additional load to the fixed-end beam. Due to the ductile nature of the steel at greater than yield point stress, a portion of the beam at each support merely deforms without carrying additional moment, and all additional moment caused by increasing the loading must be carried by the mid-span section. This mid-span section carrying a moment of $\frac{WL}{24}$ at the time yielding occurs at the end supports, can carry a total moment up to $\frac{WL}{16}$, at which point the mid-span and end moments are equal. It is evident therefore that the "collapse" load for the fixed-end beam will be at least half again that of the simple-span beam. Research Council investigations in England, and currently underway in the Welding Research program mentioned earlier, have demonstrated that the reserve strength of continuous framed structures in steel is equal to that shown by this simple example.

Based on these considerations and backed by a great deal of laboratory investigation the 20 per cent increase permitted in flexural working stress for continuous beams at points of interior support and in bending stress induced in columns by gravity loading of such beams, will be recognized as only a modest step in the direction of balancing the real capacities between continuous and simple-span design.

Let me emphasize here that these provisions do not contemplate that a plastic yielding of parts of a framework will take place. The specification is based on

conventional methods of designing structures by the Elastic Theory. This in turn is based on the behavior of steel when stressed well below the yield point stress. The stresses for full working load are kept within certain prescribed limits known as allowable unit stresses. However, the ratio of these to the minimum yield stress of ASTM, A-7 steel, (33 over 20, or 1.65 for the basic working stress) gives no indication of the real margin of strength that exists in continuous beams. It can be said, therefore, that the Specification recognizes that this reserve exists, and that should severe overloading occur there will be a redistribution of stress at overloads that are still well below those that would cause failure.

Mention was made of the fact that this quite conservative revision in the Specification points the way to an entirely new concept of structural design that is of great significance to structural engineers. I should like to expand on this a bit by telling you more of the work that is currently underway at Lehigh University.

The behavior of steel stressed in bending within the elastic range has been known and understood almost from the time when steel was first used as a structural material. However, its behavior in the plastic range, that is when it is strained beyond the point where it will return to its original shape if the load is released, is a subject of comparatively recent study.

A simple Theory of Plasticity was propounded some twenty-five years ago and firmly established as a result of actual tests on beams. Its extension to explain the behavior of rigid-frame structures remained largely speculative until about fifteen years ago when Prof. J. F. Baker of Cambridge University, England, began investigations on the behavior of portal-frames and columns subject to both bending and axial stress.

By 1945, Baker had accumulated sufficient information to be able to predict the behavior to ultimate collapse of rigid frame structure of the portal type. More important still, he saw in the Plastic Theory the possibility of evolving an entirely new and much more rational method of designing continuous beams and

rigid frames. With the collaboration of the British Constructional Steelwork Association, a method of design even more simple than that originally anticipated has been evolved.

In contrast with the theory of Elastic Design, in which maximum flange stresses are kept within certain prescribed limits, the theory of "Collapse Design" as accepted and used by the British is based on the principle that the "load factor" (i.e. safety factor determined by dividing ultimate collapse load by working load) shall be constant for all structures.

At present the British method is restricted in its application to rolled beam sections. Built-up sections are excluded until such time as theoretical development and research in the laboratory establish limits within which the behavior of sections of these types conforms with the theories of plastic action.

At the same time that these developments were taking place abroad, the possibilities of reserve strength inherent in steel structures also excited the interest of many in this country. In 1946 the Structural Steel Committee of Welding Research Council suggested that work under its sponsorship at Lehigh University should be directed toward the study of fully continuous welded frame construction with two objectives in mind:

1. To obtain a check on the validity of the assumptions that are usually made in continuous welded frame analysis under "elastic" design theory.
2. To study completely the "elastic" and "plastic" behavior of continuous frames and their components in order that the possibility of utilizing reserve plastic strength in the design of structures might be properly evaluated.

Since that date the so-called Lehigh Project has been pushed ahead rapidly under the co-sponsorship of the Navy's Bureau of Ships, Bureau of Yards and Docks, and Office of Naval Research; the American Iron and Steel Institute; and the

American Institute of Steel Construction.

One of the unique features of the investigation is that it emphasizes the testing of full-size rolled structural steel members, and fabricated component parts. Standard fabrication methods are used, and the members are tested in the "as-delivered," "as-welded" condition, so that residual stresses are present just as they would be in actual practice.

Out of the great volume of laboratory work that has been completed has come experimental corroboration of much of the action predicted by theories of plastic action. At the same time, various limitations that effect the plastic behavior are being defined.

Meanwhile, methods of mathematical analysis have been developed that permit the calculation of critical loads and deflections for a wide range of structures.

If I may be permitted to do a little speculating, I should like to state that within a relatively short time the theory of plasticity will be generally recognized in this country as one that for many types of structures has a number of advantages in its favor. The most important of these advantages, and ones that are of immediate interest to structural engineers, are the following:

1. It can save steel.
2. It affords an extremely simple design technique for otherwise complicated continuous frames.
3. It is predicated on the ideal of achieving a uniform strength throughout a structure.

To assist you in visualizing a few of the developments about which I have spoken, let's examine several photographs, diagrams, and sketches, that picture some of the structures and research work mentioned.

Figure 1: The Mississippi River Bridge at Baton Rouge, makes use of compression members with perforated cover plates.

Figure 2: The Muscatine Iowa high school gymnasium is typical of the interior appearance achieved by use of a "rigid-frame" roof system. The "knees" are that part of the main frames just above the sign "Fairfield."

Figure 3: This is one of the Wilson-type fatigue testing machines used in the research work on riveted and bolted joints. It has a capacity of ± 250,000 pounds. The machine is normally run at 180 cycles per minute. A micro-switch automatically shuts down the machine when a specimen failure occurs, either by cracking or by slippage of the connected material.

In the foreground, a double-lap 9-bolt specimen may be seen mounted in the machine.

Figure 4: Here is a schematic diagram of one side of the machine. As the drive mechanism turns the eccentric cam, at the right, the loading lever is pushed up and down to stress the specimen bolted between the pulling heads at the left. By adjusting the cam and connecting rod, various cycles and ranges of loads, from pulsating compression or tension, to full reversal (compression to tension) can be applied to a specimen.

With normal laboratory procedure, including two days for set-up and adjustment, a fatigue run of 3,000,000 cycles will require 24 hour operation of the machine for a period of approximately two weeks.

Figure 5: The Prudential Insurance Company's office building, at Los Angeles, incorporates many "light-weight" features in its construction. The spectacular savings achieved have been described in many articles. One even made the Reader's Digest.

Figure 6: 860 Lakeshore Drive, one of Chicago's newest apartment buildings, combines an exterior of steel and glass, floors built of sheet steel and concrete, and a frame of steel, all fire-protected with light-weight materials.

Figure 7: This typical section of exterior wall, spandrel beam, and cellular steel floor construction, illustrates the design used in Lever House, New York. Note

that the structure has two complete ceiling systems, the upper one for fire-protection the lower one for finish below extensive systems of air-conditioning ducts, recessed lighting, and mechanical services.

Figure 8: Faced with glass and stainless steel, floored with steel, and framed with structural steel, Lever House's 21 story tower stands out in sharp contrast to the conventional masonry wall construction of nearby structures.

Figure 9: This illustrates the two simple beams sketch B, and the continuous beam over three supports sketch A, mentioned as featured by Ripley. Note that the maximum bending moment is $\frac{wL^2}{8}$ in both cases, but that the shaded areas representing the magnitude of bending moment along the beams is quite different. The continuous beam in sketch A will carry more load.

Figure 10: This curve of bending moment, M, plotted against curvature ϕ, constitutes the basis of the "Simple Plastic Theory." At point (1) the elastic limit has been reached (The stress distribution is as shown on the diagram to the right of the cross-section of the beam). At point (2) the member is partially plastic. Point (3) is approached as a limit, termed the "plastic hinge moment."

Figure 11: A series of "knees" for rigid frames was tested by loading in the manner shown in the insert sketch. The sketches to the right show the various types investigated. Without exception, the "knees" all eventually collapsed by local and lateral instability. The lower group of curves represent performance of the straight "knees," the middle curves the tapered "knees," and the upper curves the "knees" with curved inner flanges.

Figure 12: The upper picture shows the laboratory set-up. Under test is a single-span portal frame vertically loaded at the three-eights points. The shape used in building this frame is an 8 B 13. The lower picture illustrates a portal frame fabricated from 8 wF 40 shapes. Note that at this stage of testing it has a center deflection of $\frac{1}{10}$ its span. Yet the frame is still carrying increased loads.

The "plastic hinges" are still in process of forming.

Now, my time is running out. I have attempted to cover some of the more important developments that have been brought about in one part of the structural engineering field, that of steel construction. All through the story, reference has been made time and again to the very important place that research holds in these developments.

The steel fabricating industry is not entirely satisfied, and it is not wont to rest on its present accomplishments. The requirements and demands of a growing country, the harsh realities of having to consider the threat of an atomic attack in designing tomorrow's structures, and the practical implications of new developments and techniques in the materials of competing industries, all pose problems that make continued improvement through research and engineering imperative and necessary.

Without question, structural engineering in steel is looking ahead to tomorrow - through research.

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THE MECHANICAL ENGINEER IN RESEARCH

By K. R. Daniel

Mr. Chairman, Gentlemen: I am deeply flattered at having been asked to talk to you today on The Mechanical Engineer In Research. And to have a part in helping celebrate your diamond jubilee of continuing progress.

When one surveys the field of Mechanical Engineering with its some twenty distinct professional divisions, he becomes somewhat confused. As I attempted to prepare this paper I was reminded of the tale about the farmer who in riding over his acreage one morning met one of his colored acquaintances trudging down the road with a long rope over his shoulder, trailing along behind him. This appeared to the farmer to be a bit unusual, so he called out, "John, what are you doing dragging that rope?"

"Lawd, Boss, I'se so confused I don't know whether I done found a rope or lost a mule."

Frankly, the subject I have chosen is enormous, and time will not permit a detailed discussion of any phase. However, it is hoped to point out some of the things which have been accomplished by the Mechanical Engineer and some of the problems still confronting him.

The world today looks to the Mechanical Engineer for its supply of power. Of equal importance is its reliance upon him to design, build, and operate machinery and appliances to convert raw materials of nature into useful products. In the three-quarters of a century since Mechanical Engineering has been recognized as a profession, progress in its many fields has been greater than in all the ages preceding; on land and sea, in every household and public building, and in the development of the industrial plants, the Mechanical Engineer has revolutionized our ways of doing things and raised the standards of living. Whether the power is obtained from burning of coal under a boiler, from the falling of masses of

water, or from the combustion of gasoline or oil in an internal combustion engine or the splitting of the atom, the Mechanical Engineer is charged with the duty of converting these sources of energy into forms of motion available for doing useful work. His occupation is to design and construct the necessary machines and devices, to supervise their operation, and constantly to improve them so as to get the maximum advantage with the least expenditure of time, money, and human effort.

The machines and devices that engage the attention of the Mechanical Engineer today are of recent development; but the principles on which they operate have been known for centuries, some of them from remote antiquity. Long before the Christian era the energy of running water was applied to grind corn, thus releasing the slaves of that day for other work. About 200 B.C. Hero of Alexander described a method for opening the temple doors by the action of fire on an altar, an ingenious device which contained all the elements of the "Atmospheric Engine" which was perfected in 1712. It was this later machine which James Watt in 1774 developed into a steam engine, with its essential details of the modern reciprocating engine. Hero also described a device in which steam issued from a reaction wheel; but it was over 18 centuries before Sir Charles Parsons in 1884 built the first successful reaction steam turbine.

George H. Corliss exhibited his first steam engine at the Centennial Exposition at Philadelphia in 1876. This engine was of 1000 HP, the largest built until that time. Only a few years later came the next big step in 1882. Dr. Gustof de Laval, a Swedish engineer, brought out the impulse steam turbine first proposed by Branca in 1628. These machines inaugurated the era of enormous amounts of power developed into one machine, and also the day of exceedingly efficient transformation of energy from coal to electricity.

Like the steam engine, the present-day gas and oil engines are the results of many workers operating through a relatively long period of time. The first internal combustion engine worthy of the name was built about 1675 and used gun

powder as fuel. The developments by Street in 1794 and Lenoir in 1860 bring us to the celebrated Otto engine, perfected at about the same time as the Corliss engine. The development of the internal combustion engine for automobiles and airplanes has been of great economic significance. The development of the diesel engine for marine propulsion played an important part as far back as World War I and set the pace for the development of all forms of solid fuel injection engines.

The invention and development of machine tools is one of the great contributions of the Mechanical Engineer. Precision work, as well as work on large pieces, was impossible until the engine lathe was devised. The metal planer, the shaper, machines for cutting gear teeth, and then the turret lathe appeared, on which several operations can be performed without rechucking the part being machined. The automatic screw machine, the milling machine, grinding apparatus for precise finishing, and high grade steel tools of a wide variety have been contributed by the Mechanical Engineer.

Mechanical refrigeration is not a new art; the practice of cooling bodies below the temperature of the surrounding atmosphere has been followed for ages, utilizing some method of evaporating a liquid in order to extract heat from the liquid itself. This found a practical application in 1755 in the construction of a vacuum machine freezing water by evaporation. The vapor compression machine of 1834 was the next step. This was followed by the ammonia-compression machine, built by Linde in 1873. Six years earlier the first absorption machine was in successful operation. Refrigeration machines are used today in hundreds of important industries.

The field of heating and ventilation has grown into a great mechanical engineering industry. Formerly people were satisfied with the crudest forms of heating appliances.

From the early open grate fire, heating has been developed into a science which calls for a close study of the actions of heat on the functioning of the

human body, so that today air conditioning in connection with heating and ventilation has passed through the public building stage into the home.

The Mechanical Engineer has contributed in many ways to the art of transportation. One, the modern steam locomotive, the diesel locomotive which has practically replaced it, the steam turbine locomotive and the gas turbine locomotive, developing 4500 HP from a single unit.

The originating and perfecting of the air brake, the design and building of freight and passenger cars, are but a few of his many important contributions in this great field of public service.

The design and development of material handling equipment open up a whole new mechanical field. The cross-country conveyor belt in the handling of bulk materials, such as coal and ore, ever threatens the railroad.

Research has either been the beginning of, or has had a leading part in, the development of every modern industry. New processes, new machines, new materials and new applications of these materials have been developed through research. Under present conditions an industry can thrive and develop only through discoveries and their applications.

What is understood by the term "Research"? And how is it carried on? Popular writers make it appear that the results of research are the works of genius. Many developments, according to these authors, are the result of a flash of inspiration or imagination on the part of the person who conducts research. Nothing is said of the long step by step search for the desired solution of the problem, nor of the many persons who may have contributed time, thought and effort toward the final result. The day of Watt and his teakettle is over. The experimenter in his attic can no longer keep pace with the demand for scientific application to industry.

In pure research the scientist searches out new truths of nature and of the elements that occur on the earth. He is generally not interested in practical

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In pure research the scientist searches out new truths of nature and of the elements that occur on the earth. He is generally not interested in practical

applications of these truths. These scientists are our great explorers. They open up new territories of knowledge. One may take as an example of such pure research the discovery of Lord Rutherford and his associates of the possibility of splitting the atom.

Industrial research is concerned with the exploration of new fields of knowledge or old fields, usually with a definite object in mind which will, when successful, repay the cost of the research and bring forth new products to benefit mankind and yield a profit. It is in this applied or industrial research that the engineer has made his great contribution.

In general, the engineer realizes a need and then studies the results of pure science to find by research a means to satisfy this need.

Research has grown some fifty-fold in the United States in the last 30 years, and continues to grow. Today the United States is spending more than five times as much as it did ten years ago, and consequently its research position is the strongest in the world.

According to Dr. Clyde Williams, Director, Battelle Memorial Institute, Columbus, Ohio, in 1940 the U. S. spent 345 million dollars on science and research. Today we are spending at the rate in excess two-billion a year.

The Mechanical Engineer has contributed remarkably to the transportation industry, both land, air and sea. His basic research in extending the steam tables, his constant study of the behavior of metals at high and low temperatures. His study of vibration as applied to all types of machines has resulted in steam generating units which have advanced from 1920 plants which produced power from steam at 200# pressure and 550° F. at the rate of 3# of coal per KWH to those being installed today which operate at 2400# pressure and 1100° temperature, and produce a KWH for approximately .8 lb. of 12,500 BTU coal.

The jet and gas turbine aircraft engine, the guided missile and - now in building - a nuclear plant for marine propulsion.

In the machine tool industry, metal is being cut at fabulous rates; horsepowers have increased approximately three-fold since the advent of the cemented carbide tools. And a new concept in tool cooling which is a recent invention of Mr. R. J. S. Pigott, Director of Engineering Division, Gulf Research and Development Co., and past president of the American Society of Mechanical Engineers, bids well to surpass anything we have hoped for with cutting speeds increased 100% and tool life increased from 5 to 12 times.

The design of huge closed die forging presses up to 50,000 tons to produce large forgings and extruded shapes for the new type aircraft.

These are the spectacular results of the Mechanical Engineers' research.

Every industry which converts raw materials to usable products is dependent upon the machines designed by the Mechanical Engineer. In no industry has a greater revolution taken place as a result of his machines than the cast iron pressure pipe industry with which I am associated. Until approximately 30 years ago the industry had advanced little; the manufacturing processes in use were a combination of art and manual labor. Today the modern pipe foundry is completely mechanized, producing centrifugally cast iron pipe weighing as much as 6 tons per 16' length with practically no manual labor. The centrifugal process for manufacturing cast iron pipe has been extended to produce heavy wall steel tubing in both carbon and stainless steels and bimetallic tubing. This tubing has opened a whole new field of research in its application to steam plant work, wind tunnel and shipshafting, hydraulic machines, electric motors requiring unusual magnetic properties, guided missiles and hundreds of other uses which formerly required bored forgings.

Today the Mechanical Engineer is engaged in the expansion of research already in progress on the basic properties of materials at high and low temperature. The work at high temperatures is of the greatest importance in increasing the efficiency of heat engines of all kinds; the work at low temperatures has direct applications in the design of refrigerating machinery.

General development and application of elastic theory to mechanical engineering design and vibration problems which arise in modern mechanical engineering.

Detail study and application of fundamental knowledge of fluid mechanics to mechanical engineering problems; steam turbines, and boilers and hydraulic machinery of all kinds are particular examples.

A fuller understanding of the behavior of lubricants, not only in journal bearings, but in oscillating motions and in gears; and, in cooperation with chemical research, the development of improved lubricants.

The basic science of Kinematics and mechanisms which is fundamental to the design of machine tools and production machinery of all kinds. The development of more accurate measuring instruments.

The development of the basic mechanics of forging, shearing and cutting of metals.

The study of problems in heat transfer which are common to almost every branch of mechanical engineering. Knowledge of thermodynamic properties of working fluids in heat engines and refrigerating machinery over a much wider range of temperature and pressure than is at present available is essential for further progress.

And now a word about the future of Mechanical Engineering Research in our own South and the opportunities for those who desire to pursue it.

We are, as has been stated many times, living in an area which is being industrialized at a rate exceeding any other area of the country. In an area comprising a little less than 1/3 of the total area of the country. We now have a little more than 1/3 of the population. From the "Blue Book of Southern Progress" published in Baltimore, Maryland, we find some rather interesting trends. In 1939 the sale of all manufactured goods in the U. S. amounted to some 57 billion dollars. In the same year the sale of manufactured goods in the South amounted to 11 billion dollars, or a little less than 20%; in 1951, based on the same 1939

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COMMERCIAL AVIATION IS HAMPERED BY WAR

Address delivered by

Grover Loening -

Mississippi State College

April 25, 1953

Swimming against the tide is always a difficult operation but frequently it is the only way to get to the other shore. And the other shore in aviation that we must reach and to which we can devote some time today is to study whether we can build up a commercial air industry out of our vast military development.

Obviously, under our present air operation, this is both an unpopular and sparsley populated field to survey. We have become so spoiled and accustomed to the psychology and the modus-operandi of the Federal Handout that it takes a good deal of detachment to look at it with a cold and fishy eye, to see if it is really good for us.

The Hand-outers in the government, quite naturally are inclined to feel that their expenditures of billions of dollars constitute the main wherewith-al on which civil aviation is to be allowed to live.

But it so happens that some of us who have been in this business a long time and have seen it grow from nothing at all are not completely sold on this philosophy. We have seen it in action, particularly in the past few years - and we have seen it woefully wanting. All we have to do is to look at some statistics. Twenty-nine million automobiles - private vehicles of transport - are woven intimately into the life of this country to such a degree that crowded streets and roads are making the automobile increasingly impractical. But still automobile production is on an ascending curve. During this period of the last decade, hundreds of thousands of people have learned to fly, but we see exactly the opposite taking place

in the development of a vehicle to utilize the vast free roads of the air instead of the costly and inadequate surface facilities. Private flying, or individual flying, or whatever you wish to call use of airplane as the personal vehicle of a citizens' life, has decreased consistently since the end of the war.

In the last four years - the last two in particular - the Military have undertaken an enormous activity in research, and the expenditure of huge sums for construction of aircraft, as well as the use of huge tonnages of rare and difficult-to-get raw materials. But one searches in vain for any serious contribution to the development of the individual's vehicle of the air, that he could really use.

The blame is not all on the Pentagon - let us all get that straight right now. The blame is on the starry-eyed individuals who by some facile stretch of the imagination have gotten themselves into believing that war development of aircraft is a powerful stimulus to the development of commercial air operations. It is the privilege of some of us to disagree on this and if we can prove that we are right, it is certainly our duty to call attention thereto. Let us give it at least a preliminary look-over.

As far as the public is concerned, let us start with what bothers them most - NOISE - and this should be written in large capitals. Here is a field the correct solution of which is vital to the proper progress of civilian use of aircraft in great quantity. What has the Military contributed to this in the last twenty years? One seeks in vain for a requirement in the Requirements Division of our great Air Force - for example - for a serious research or development program that would reduce the outrageous noise of modern aircraft. Perhaps recently this may have been altered. If so, it is no doubt marked "secret". If there are some secret projects on noise elimination on which some of the funds of the Air Force are now being spent, it is very poor public relations for the Air Force to keep it a secret. The detection of aircraft of an enemy is by radar and not by World

War I listening posts. But the deafening noise of four-engine Globe Masters taking off on practice flights continues from five in the morning till late at night over some civilian cities. This will not sufficiently receive the attention of the Military until that day will come when the public will just go into plain revolt and stop the nuisance. Load carrying planes like the Globe Master, when on practice and training flights, could readily carry the extra weight of muffling equipment and thus become a better neighbor to the long suffering people who happened to have been foolish enough to think that a nearby great Air Force airport installation would help their business. If this noise question were taken seriously from a purely commercial angle, the companies building aircraft would soon be in competition with each other for the quietest airplane as being the one that individuals and airlines would purchase in order to prevent their usage being hampered by local noise abatement ordinances, which are almost certain to come up in the next few years.

Next we have the problem of airports themselves. We accept with a blind and foolish faith the dictum that next year's airplane being a faster airplane must of necessity have another thousand foot length added on to the runways it will use. Military designers almost invariably dismiss landing area restrictions as something for someone else to worry about. The Air Force has a few half-hearted projects that have to do with the so-called "Assault-type" of aircraft that is supposed to land in small fields near front lines - but the bulk of the programs for development of engine installations of wings, of landing gears and various aircraft configurations all done at a cost of hundreds of millions of dollars a year, proceed with little regard towards shorter runway progress.

In the Military mind - and in many ways quite naturally - the thought of slow speed is abhorent. To the Military it unconsciously casts a reflection on the skill of the pilots who are not concerned by increasingly dizzy landing speeds, and also

because the Military of course must give their attention to air combat at high speeds as their prime business.

The result is an unmistakable fact that attainment of very slow landing speeds instead of becoming a "must" to be attacked with the greatest energy, over every possible avenue that offers shorter landing and quicker takeoff - particularly on jet airplanes - the entire matter is pretty much ignored and receives a most unsymphathic ear when attention is called to it at the Pentagon.

There are many technical avenues in the existing art and science of aviation that would lead quite surely to a tremendous reduction in the landing speed of fast aircraft and equally great reduction in the distance required for takeoff. Some of us who have studied this problem refer to it as the phase of quite nearly "vertical-flying". The helicopter, of course, can do this. But the helicopter, as such, is limited by its inability to achieve high speed in the air due to the edgewise progress of the rotors and the unequal condition of the advancing and retreating rotor blades. Helicopter engineers have for years conceived of a combination of a rotating and fixed wing aircraft called a "convertiplane" which would rise on its rotors in the vertical phase of flying and then fly on its fixed wings at high speeds in the horizontal phase. This is one solution - but by no means the only one - there are others. What is of great importance to realize right now is that these solutions seldom originate with the Military. Only recently an inventor, with very limited facilities, has brought out - for example - an interesting step in this general direction called a "channel-wing" in which the tip of the propeller sucks air over the wing while standing still and generates a considerable lift on the aircraft. An even more promising method of vertical flight can be envisioned when we contemplate jet engines and the thousands of pounds of air a minute that they set in motion. The present configuration which seems to be the limit of the Military imagination is the simple air jet thrust out of the tail pipe.

But there are many jet dispositions and configurations possible with suitable ducts that would enable the achievement of a design in which the energy of the jet engine draws air over the wing and exhausts it at the trailing edge in a large sheet much slower than the cylindrical discharge of the ordinary jet tail pipe. Thus there would be achieved an induced lift of great magnitude in the desired vertical flying direction. Then by gradually transferring this lifting duct flow to a tail pipe thrust flow, the induced lifting air flow is changed into pure thrust and the airplane becomes a fast jet driven craft. Incidentally in this concept it is of interest to note that the noise of a jet airplane is due principally to the high velocity of the jet exhaust through a small constricted tail pipe. If the same volume of air movement were exhausted over the whole surface of the wing at a very much smaller velocity the noise would be tremendously reduced and this would be a type of flow near the ground on take off and landing that would be much less objectionable to the neighbors. Also in this area of development of higher lift there is great promise for the boundary layer conceptions that Dr. Raspet and his staff at Mississippi State College have already worked out. Still another method of achieving vertical flying regime with a fast aircraft is to so overpower it with rockets or turbo-prop installations that the thrust when the aircraft stands on its tail will raise it vertically, after which the craft would turn ninety degrees and then fly fast horizontally. On landing, this type of aircraft assumes the vertical position and lets itself down on its power. It is to the credit of the Military of several nations to point out that this concept is receiving some experimental attention. It is an old concept but a very awkward one.

Then of course there is still another field, greatly explored by the Navy in its highly successful carrier operations, which is to accellerate for a quick take off by a catapult and land on a very small area by a hook engaging landing

wires. It is rather surprising to contemplate that the Air Force does not seem to have given very much attention to the possibility of using this system in front-line small field operations, nor has it received any serious Civil Aviation appreciation.

Consideration of all of these possibilities gives a particularly pungent importance to a comment that was made to your lecturer by the late Henry Ford Sr. at an air show in Detroit in 1926. This great mechanical genius and natural-born-engineer had an unfailing insight and one can never forget that when he looked over the assembled airplanes he waved his hands and said,"These things won't amount to anything until they use their power to land with". How right he was and how far afield has our progress been! The airplane as a vehicle must operate from a back-yard, that is for sure.

Another area in which the Military development of aircraft greatly differs from, and definitely hampers, the development of civilian aeronautics, is in the manufacturing, procurement, inspection, and testing procedures. No criticism can be made of the Military on the fact that they need pretty much the system they have in order to get things the way they want them at the front - but to translate this method of doing business as being helpful to the development of commercial aviation is a very gross mistake. Particularly is this true now of the present aircraft business, where the complications that Military agencies have introduced are so great that the whole process of meeting specifications, inspections, and testing has gotten into astronomical figures of expense that no commercial operation could find profitable. A great commercial business like the automobile industry, for example, is not run this way. How could we possibly have our millions of cars if every customer required exhaustive stress analysis of every part, and their submission to him for his approval and inspection with the customer watching over the construction to see first that the material specified is used and second that it

is fabricated as intended. Commerce in order to be economical must rely on faith, reputation, and the honesty of the maker of a product. But in the military system, this is not recognized. The expense that ensues in the Military way of procuring an item kills its commercial possibilities at once.

The Military services, in their continuing requirement for greater appropriations, naturally feel that the public would more easily swallow the cost burden of our war-like situation if the Air Power expense were to be propagandized as the surest basis for future commercial advances. But the Pentagon Air Power authorities, properly ambitious as they are in their own field - delude not only the public but themselves by not calling attention to the fact that Military requirements and procuring systems are far different from what Civil Aviation needs.

During the last two years, there has been going on in Washington the process that is called "broadening the base" - of our aircraft manufacturing potential. This is of course necessary only because our commercial base of aircraft production is so small. If we could enlarge this to be something like the automobile industry is in peace time, it would not be necessary to "broaden the base" by bringing automobile people in to build aircraft. There would be aircraft people ready to proceed with the military versions of their already developed products.

Then we come to the question of pilot training. This would certainly at first glance seem to be helpful to civilian aviation - but as a matter of fact it is not - except in a small degree that has to do with familiarity. The military pilot is trained all wrong for civilian flying. To begin with he is trained in acrobatics which should be absolutely prohibited in civilian aeronautics. He is trained to take risks in getting his mission done and he is trained that if he loses a plane he gets another from the reserve fleet. The civilian avaition pilot should start out with a completely different psychology from the very beginning of his training. The civilian psychology should be a veneration and a love of his little plane with almost a tender regard to see that it is not scratched. And the civilian pilot

should be taught good manners and a high regard for the civilian public around him - not to blow dust in their eyes and not to make more noise then he has to and to do so at reasonable hours. And above all, he should be taught to be extremely careful of the waste of material and to cherish every item of his equipment on which money has been spent.

It was civilian thinking that introduced into the Pacific Air War a very much keener concept of the importance of fuel economy than the Military had given any attention to. This was the work that Lindberg did when he added hundreds of miles to the range of fighters by just working out in detail how to handle the fuel for maximum economy.

In the military establishments, growing ever bigger as they do, there is a natural tendency to add divisions, departments, and additional units of personnel. This, in a great measure, is responsible for the increasing complications in aircraft. Every little department wants to get its gadget into production - and all, mind you, in a perfectly honest conscientious effort to get the best aircraft. The best example of the increasing complication and bureaucratic growth that would make commercial development under any such system highly impractical is to recall that the inspection teams to look over a mock-up of a military plane a decade or two ago consisted of four or five officers. Today, a mock-up board consists of over one hundred men - each with his own little insistance of what he wants on the poor little aircraft. There is no encouragement for civilian avaition in any set-up such as this.

Airline development has, to be sure, been one in which engine, instrumentation and other military work have been most helpful. But as a business for a big industry the production possibilities of airline planes could not alone be relied on to fill the gap if the military emergency were to stop. I need hardly remind you that the tremendous air travel in this country is done by only a little over a thousand

planes. International air travel has now assumed tremendous figures in which last year one million three hundred thousand passengers were carried by international airlines of the United States, three hundred thousand more passengers traveling by air then by ships. This was all done however by a small fleet of only two hundred and thirty-four planes. On a twenty percent replacement rate, the airline market for our huge aircraft industry would only total 400-500 transport planes a year.

It is in the private use of planes that the big market that will fill the gap and create a great industry will be found. This is already beginning to be evident in the executive aircraft field which has now grown up to a thousand planes at a value of forty-eight million dollars annually - used by a growing list of two-hundred and forty business firms. Then there is a slow but steady growth in farm and crop dusting aviation. But the use of aircraft as a personal vehicle is almost negligible. This is the field that needs development most and it gets the very least from the Military at present.

The top engineers - the real geniuses whose skill is so evident in our fine military airplanes - have not given much attention to this field - in fact they cannot. They are too engrossed in their Military problems. And it is pretty evident that we have not made much progress in this field when we realize that for several years after the war all that we could come up with for the personal private aviator - up to a year or two ago - was the "Cub" class of aircraft and re-worked war types.

It is certainly possible in the present state of the science and art of aviation to see in the future, quite soon - if we could only get busy on it - an aircraft at modest cost that could take off and land vertically and fly fast horizontally and that could have its difficult balancing technique done by automatic pilot, leaving only steering and speed control to the occupant. We may even see the day when we will have worked out a radar safety landing system that will insure

a safe landing even if the pilot is asleep at the switch. It is in such a vehicle that a person with poor eyesight and avanced age could drive as safely as an automobile.

Landing and taking off on very small private areas and traveling in traffic at ten to hundreds of miles an hour is in the immediate future and it is this that will create a great peacetime industry. Military development is just not capable of doing it, because the requirements, the philosophy, the method of approach are all so totally different. So when you read that Air War development is a great stimulus and help to Civil Aviation and the coming Air Vehicle Age, take it with a very large grain of salt.